HIGH RELIABILITY ORGANIZATION AND APPLICABILITY TO THE BATTLEFIELD TO REDUCE ERRORS ASSOCIATED WITH COMBAT CASUALTY CARE

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Healthcare delivery is in need of a significant paradigm shift to decrease the amount of preventable error. Healthcare delivery is not likely to become simpler but become more complex in the future and its complexity will likely transfer to the battlefield. The journey of the Military Health System (MHS) to become a High Reliability Organization (HRO) started when former Secretary of Defense Chuck Hagel ordered the first review in the history of the MHS on May 28, 2014. This report shaped the framework for the MHS to combine the concepts of an integrated health care system with the principles of HRO. Implementation of HRO tools within healthcare the last five years have displayed in many healthcare organizations and specialties, a significant decrease in preventable errors and decrease costs associated with it. Application of HRO concepts within the MHS, will likely decrease preventable error in deployed environments across the echelons of care, save countless lives, and conserve the fighting strength and support our Armed Forces.

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necessarily represent the views of the U.S. Army Command and General Staff College or
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statement.)

ABSTRACT

HIGH RELIABILITY ORGANIZATION AND APPLICABILITY TO THE
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CASUALTY CARE, by MAJ Johnnie Robbins, 119 pages.

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ACKNOWLEDGMENTS

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ACRONYMS

ADE   Adverse drug event

ADRP   Army Doctrine Reference Publication (United States Army)

AE   Adverse event

AHRQ   Agency for Healthcare Research and Quality

AHS   Army Health System

AMEDD   Army Medical Department

CPQ   Clinical Practice Guideline

CQM   Clinical Quality Management

CRM   Crew Resource Management

CSH   Combat Support Hospital

DOD   Department of Defense

DOW   Died of Wounds

EBP   Evidence Based Practice

FMEA   Failure Mode and Effect Analysis

HFACS   Human Factors and Classification System

HRO   High Reliability Organization

IHI   Institute for Healthcare Improvement

JP   Joint Publication (United States Department of Defense)

JTTR   Joint Theatre Trauma Registry

KIA   Killed in Action

MEDCOM   Medical Command

MHS   Military Health System

MTF   Medical Treatment Facility

NM   Near Miss

SECDEF   Secretary of Defense

TeamSTEPPS   Team Strategies and Tools to Enhance Performance and Patient Safety

TJC   The Joint Commission

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CHAPTER 1

INTRODUCTION AND OVERVIEW

Our Service members and their families deserve the highest quality healthcare possible wherever they are station or deployed. In recent years, the Department has made great improvements in our health care delivery system – nowhere more important than in improving trauma care, which has resulted in the highest ever survival rate from battlefield injuries.

It is our continuing obligation to those who serve, and all beneficiaries of the Military Health System (MHS), to continually review and improve our standards of care and the system that delivers that care. To ensure we are meeting these standards, I am directing a 90-day comprehensive review ("Review") of the MHS, effective immediately.

— Secretary of Defense Chuck Hagel
Memorandum for MHS, May 28, 2014

Overview

The journey to become a High Reliability Organization (HRO) began when

former Secretary of Defense (SECDEF) Chuck Hagel ordered the first enterprise review

in the history of the Military Health System (MHS) on May 28, 2014. The purpose of this

review was to assess whether: (1) Access to medical care in the MHS meets defined

standards; (2) The quality of health care in the MHS meets or exceeds defined

benchmarks; and (3) if the MHS has created a culture of safety with effective processes

for ensuring safe and reliable care of beneficiaries (U.S. Department of Defense 2014).

The final report released of the *MHS Review* on August 29, 2014 shaped the framework

for the MHS to combine the concepts of an integrated health care system with the

principles of HRO (U.S. Department of Defense 2014).

So why HRO? HROs are traditionally organizations that consistently conduct

high quality and reliable operations, free of error over a sustained period of time. These

HROs are not a new concept to the military. In fact, the military is one of the first organizations to lead and help develop these HRO concepts in its aircraft carriers, submarines, and flight squadrons. These military HROs maintained a high operational tempo and prevented mistakes that if not caught in time would have led to catastrophic events to include loss of life (Roberts 2003).

In 2001, Weick and Sutcliffe recognized that successful HROs displayed characteristics that they coined created a collective mindfulness to reduce preventable error and maintain high quality and reliable operations. They further turned these characteristics into five principles: preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and deference to expertise (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

The main purpose of this thesis is to review current HRO tools in healthcare that have reduced preventable error, how to measure it, and its applicability to deployed environments. It is important to mention that this journey to HRO is not just within the MHS, but all healthcare systems in general across the U.S. These organizations within the U.S. are working diligently to apply these concepts incrementally to improve their systems to prevent disastrous events that have led ultimately many times to a loss of life and function (Chassin and Loeb 2013).

Background

In spite of the latest advancements in medicine to promote a culture of safety, quality initiatives, and leveraging technology to improve patient care, the U.S. healthcare system has not been able to decrease the number of preventable deaths that occur

annually. In November 1999, the Institute of Medicine (IOM) released a landmark review, *To Err is Human*. The review revealed statistics of an alarming death rate of 98,000 people dying each year as a result of medical errors (Kohn et al. 1999). This rate exceeded the combined number of deaths from motor vehicle accidents, breast cancer, and AIDs to become the eight largest cause of death in the U.S. annually. In April 2011, an article in *Health Affairs* identified more than 1.5 million preventable errors occur annually in the U.S. healthcare system (Bos et al. 2011). In September 2013, the *Journal of Patient Safety*, released an even higher statistic of 440,000 deaths are caused annually by preventable harm (James 2013). This shocking statistic would surpass the Centers for Disease Control and Prevention leading cause of death by chronic lower respiratory diseases as the third leading cause of death and would only trail deaths caused by cancer and heart disease (Center for Disease Control and Prevention 2013).

Major industries outside of healthcare that have implemented HRO concepts have shown a significant decrease in preventable errors (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015). It is important to mention that there is no well-documented evidence of hospitals that have transitioned from a low-reliability into a high-reliability organization and sustained that accomplishment. However, a growing body of evidence is demonstrating that application of HRO concepts and tools will in fact decrease harm caused by preventable error (Chassin and Loeb 2013).

<div align="center">Primary Research Question</div>

What HRO tools can be used by the Military Healthcare System to decrease preventable error in deployed environments?

1. What HRO strategies can be used to decrease preventable error in deployed environments?

2. What HRO tools can we use to measure preventable error in deployed environments?

3. What challenges and opportunities exist to implementing HRO tools in deployed environments?

Assumptions

There are several assumptions within this study that will likely remain true and that are relevant to this research endeavor. The primary assumption is that despite building the concepts of high reliability in the MHS, deaths are still likely to occur from preventable error now and in the future. Second, the MHS has already started its journey to becoming a HRO and the information in this thesis will likely add to the growing body information used. Third, finding consistent metrics to measure high reliability may be different throughout the MHS. Finally, it is likely that there may be considerable risks taken in deployed combat environments that may increase preventable error. These additional risks may pose a challenge to building high reliability to decrease preventable error in the MHS due to the austere environments with limited resources in a deployed combat environment.

Key Definitions

Active Error: An error that occurs at the level of the frontline operator and whose effects are felt almost immediately (Kohn 1999).

Adverse event: A patient safety event that resulted in harm to a patient (Joint Commission 2015).

Clinical Quality Management: A systematic, organized, multidisciplinary approach to the ongoing assessment, monitoring, evaluation, and modification of the process of healthcare and services to enhance quality (DeLorenzo and Pfaff 2011).

Close call: A patient safety event that did not reach the patient often referred to as a near miss or good catch (Joint Commission 2015).

Health care organization: Entity that provides, coordinates, and or insures health and medical services for people (Kohn 1999).

High Reliability: Indicator of reliability that is measured by performance in process outcomes, reduction in error rates, and operations that result in safe, high-quality environment nearly free of error (Weick and Sutcliffe 2015).

High Reliability Organizations: Organizations that have in place high reliability designs to protect from potentially disruptive, catastrophic events, assure high performance in managing the unexpected in an increasingly complex world (Weick and Sutcliffe 2015).

Human factors: Study of the interrelationships between humans, the tools they use, and the environment in which they live and work (Kohn 1999).

Latent Error: Errors in the design, organization, training, or maintenance that lead to operator errors and whose effects typically lie dormant in the system for lengthy periods of time (Kohn 1999).

Medical Error: Failure of a planned action to be completed as intended or use of a wrong plan to achieve an aim (Kohn 1999).

Military Health System: The Military Health System (MHS) within the Department of Defense (DOD) that serves almost 10 million Americans entitled to health care coverage. The MHS is a global healthcare system that has over 50 hospitals, 600 clinics staffed with 150,000 military and civilian personnel and has an operating cost of $52 billion dollars (U.S. Department of Defense 2014).

Mindfulness: Heightened state of involvement and wakefulness or being in the present (Langer 2000).

Patient Safety: Freedom from accidental injury, ensuring patient safety involves the establishment of operational systems and processes that minimize the likelihood of errors and maximizes the likelihood of intercepting them when they occur (Kohn 1999).

Patient safety event: An event, incident, or condition that could have resulted or did result in harm to a patient. A patient safety event can be, but is not necessarily, the result of a defective system or process design, a system breakdown, equipment failure, or human error (Joint Commission 2015).

Preventable error: An adverse event attributable to error caused by medical management rather than the underlying condition of the patient. These events are considered to be preventable and often result in error because of a system design flaw (Kohn 1999; Joint Commission 2015).

Quality of care: Degree to which the health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge (Kohn 1999).

Reliability: The likelihood that an organization, a process, or individual within an organization will operate correctly each and every time. Reliability is directly tied to error rates that are caused by human and system factors (Weick and Sutcliffe 2015).

Roles of Medical Care: A characteristic of health support is the distribution of medical resources and capabilities to provide roles of medical care. Policy provides the framework from which the medical community derives the direction and identifies the requisite people, materiel, facilities, and information to promote, improve, conserve, or restore well-being (U.S. Department of Defense 2012).

Role 1: The first medical care military personnel receive is provided at Role 1, also referred to as unit-level medical care (U.S. Department of Defense 2012).

Role 2: Provides advanced trauma management and emergency medical treatment including continuation of resuscitation started in Role 1. Role 2 provides a greater capability to resuscitate trauma patients than is available at Role 1 (U.S. Department of Defense 2012).

Role 3: The patient is treated in a Medical Treatment Facility (MTF) or veterinary facility (for working animals) that is staffed and equipped to provide care to all categories of patients, to include resuscitation, initial wound surgery, and post-operative treatment. This role of care expands the support provided at Role 2 (U.S. Department of Defense 2012).

Role 4: Medical care is found in US base hospitals and robust overseas facilities. Mobilization requires expansion of military hospital capacities and the inclusion of Department of Veterans Affairs and civilian hospital beds in the National Disaster Medical System to meet the increased demands created by the evacuation of patients

from the area of responsibility. The support-base hospitals represent the most definitive medical care available within the medical care system (U.S. Department of Defense 2012).

Standard: A minimum level of acceptable performance or results or excellent levels of performance or the range of acceptable performance or results (Kohn 1999).

Limitations

There are several significant limitations to this study. Several articles describe the HRO concepts in the military in reference to aircraft carriers, nuclear arsenals, crew resource management, and submarines. However, there is none in military healthcare. There is no current research available to measure high reliability in deployed environments. Finally, this thesis does not address in depth the challenges of implementing the tools to develop high reliability. It is an understatement that implementation of these tools in any environment would cause a rapid change. However, the implementation of the tools to build high reliability is a starting point towards decreasing preventable error in deployed environment settings.

Scope

The thesis will assess feasibility, acceptability, and suitability of the tools to build high reliability to decrease preventable error in deployed environments. The MHS is unique and the high reliability tools derived from this study may not be applicable in all elements of operation within it. This study is specifically limited to the HRO tools implemented in hospital settings and its applicability to decreasing preventable error in deployed environments.

Delimitations

Delimitations of the study are set to analyzing the HRO concepts that build high reliability to decrease preventable error. There are likely additional tools outside of HRO concepts that decrease preventable error. However, HRO tools provide a systematic and comprehensive approach to decreasing preventable error. An additional delimitation is the literature review consisting of articles within PubMed and within the dates of 1 January 2011 to 31 December 2015.

Significance of the Study

The purpose of this study is to analyze the possible effectiveness of HRO tools to decrease preventable error in the deployed environment. HRO is a current topic that the Secretary of Defense (SECDEF) and the other Surgeon Generals are using as a strategy to improve healthcare delivery within the MHS (U.S. Department of Defense 2014). Across the MHS, HRO concepts have been implemented in garrison facilities with further plans to implement in deployed environments.

Healthcare delivery is in need of a significant paradigm shift to decrease the amount of preventable error. Healthcare delivery is not likely to become simpler but become more complex in the future and its complexity will likely transfer to the battlefield.

Implementation of the high reliability tools within the MHS could prove noteworthy especially if it decreases preventable error that would save countless lives and prevent litigation that costs millions of dollar annually. The applicability of providing tools that decreased preventable error now in deployed echelons of care will conserve the fighting strength and support our Armed Forces.

Summary and Conclusions

       The purpose of this study is to analyze the possible effectiveness of HRO tools to decrease preventable error in deployed environments. Chapter 2 will provide a brief literature review of the historical context of HRO concepts to include recent applications of HRO in healthcare to include the MHS. The literature review will also include a comparison of the tools and their outcomes organized within the current HRO principles utilized to restructure healthcare systems to become highly reliable. Chapter 3 will describe the methodology of the research conducted for this thesis using consort diagrams and level of evidence tables. Chapter 4 will analyze the HRO tools found in the literature review available and their possible applicability for deployed environments. Chapter 5 will provide conclusions to the research questions and recommendations for the applicability of high reliability tools and further additional research.

CHAPTER 2

LITERATURE REVIEW

<u>History of HROs</u>

This chapter's goal is to conduct a literature review and share historical contexts of HRO implementation and examples how the concepts are used to decrease preventable errors in hospitals. As with many concepts and theories, there has been an evolution in applicability over time. Chapter 4 will reveal the results of the recent five-year literature review.

HRO concepts are not something new to the military. Researchers in World War II have been seeking to understand the human factors that contribute to error in war. The research exposed the human factors associated with the failure or success of equipment designs and human effectiveness in times of war (Roberts 2003). This included the human factors associated with error that led to disasters in times of war. The researchers began to understand that disasters did not normally happen overnight. There appeared to be an incubation period of a sequence of failures and errors that would lead to disastrous events. This provided the framework for a sociological approach to analyzing error and behaviors to disasters (Roberts 2003).

After World War II, the majority of research focused on disaster response. It was not until 1978, Barry Turner's *Man-Made Disasters*, that the focus changed from disaster management to disaster prevention (Turner 1978). Building upon the World War II research, several professional disciplines (psychology, physics, and engineering) began to analyze the multiple factors that leads to error and contributes to disaster. The theory resided in understanding the precursors of events, especially the human factors and its

key to preventing disasters (Roberts 2003). These insights began to take hold and created the budding theories and applications of high reliability to be studied in the operations of: aircraft carriers and their flight decks, nuclear submarines, nuclear plants, aviation to include airport security, electric companies, railroad operations, firefighting, banking, and more recently in healthcare (Weick and Sutcliffe 2015).

Commercial aviation is the first organization to officially develop HRO-like principles (Roberts 2003). This transformation occurred because of a United Airlines accident in Portland, Oregon in 1978 that killed 10 and injured up to 175 additional passengers. The probable cause of the accident was the "failure of the captain to monitor properly the aircraft's fuel state and to properly respond to the low fuel state and the crew-member's advisories regarding fuel state" (Killen 2014). This in turn created a research group to develop applications focused on team-building and improving communication to decrease or prevent errors appropriately named "Crew Resource Management" (Roberts 2003). Crew Resource Management (CRM) ensures that crews are trained in a method where everyone has a voice in identifying problems and what can be done to solve them (Killen 2014). CRM training programs enhances flight crew communication, decision-making, and removes the hierarchal elements that come with decision-making and ensure those with knowledge of the problem have a voice in fixing it (Roberts 2003). CRM is now widely adopted across the aviation industry to include military aviation. CRM is credited with making flying safer, by reducing the number of airline accidents through preventing errors and increasing reliability (Killen 2014).

Normal Accident Theory

After the flight incident in Portland, Oregon, the aviation industry tackled the challenges of decreasing error and becoming more reliable. *Normal Accident Theory* by Charles Perrow became an explanation of why accidents happen especially in large organizations (Roberts 2003). In 1984, Perrow conclusions were based on his research from the infamous *Three Mile Island's* nuclear incident. Perrow concluded that organizations with high-risk technologies, despite their best efforts would suffer from system-wide failure and catastrophic accidents. Perrow's primary reason for why these accidents happen is due to organizations being highly complex and tightly coupled. The complexities and tightly coupled systems offer little slack in the system, which prevent organizations the inability to detect unexpected events that lead to failure, manage them, and resume normal operations (Perrow 1984). However, this set the stage for organizational theorists to argue that high-risk organizations are able to avoid failure despite complexity and tight coupling. These organizational theorists believed that organizations could operate high-risk technologies at the same time decrease errors and failures. The concepts proposed is that if organizations adopted high reliability practices and engrained it within their organizational cultural norms they could avoid failure despite complexity and tight coupling, and rebound quickly from failures to maintain normal operations (Roberts 2003).

Human Factors

The study of human factors that lead to error has been studied for several decades, in particular in aviation and recently becoming applied to healthcare (Brennan 2015). Human factors study is described as "the study of how interactions between

organizations, tasks, and the individual worker impact on human behavior and systems performance" (Bion 2010). Psychologist James Reason is one of the most noted pioneer researchers in the study of human factors impact on error among various fields to include healthcare. His research on human error established a foundational concept of how various factors when lined up could cause an adverse event or error (Reason 1990). His Swiss Cheese model of human error is one of which many are familiar. Reason concluded that when humans make an error it is rarely one event that caused it but instead a myriad of factors that contributed to it (Reason 1990). These contributing factors are multifactorial involving human factors, technology, environment, and system operations (Reason 1990). These factors are often categorized into four levels and depicted as slices of the Swiss Cheese model: organizational influences, unsafe supervision, preconditions to unsafe acts, and unsafe acts (Reason 1990). Essentially, each slice represents a potential barrier to error and the holes represent a possible breach to each barrier (Reason 1990). When the holes of the each barrier line up, an adverse event or error occurs that could lead to a disastrous outcome (Reason 1990). Reason's Swiss Cheese model displays the continuum of how error transitions from latent failure to finally into active failures that could lead to harm.
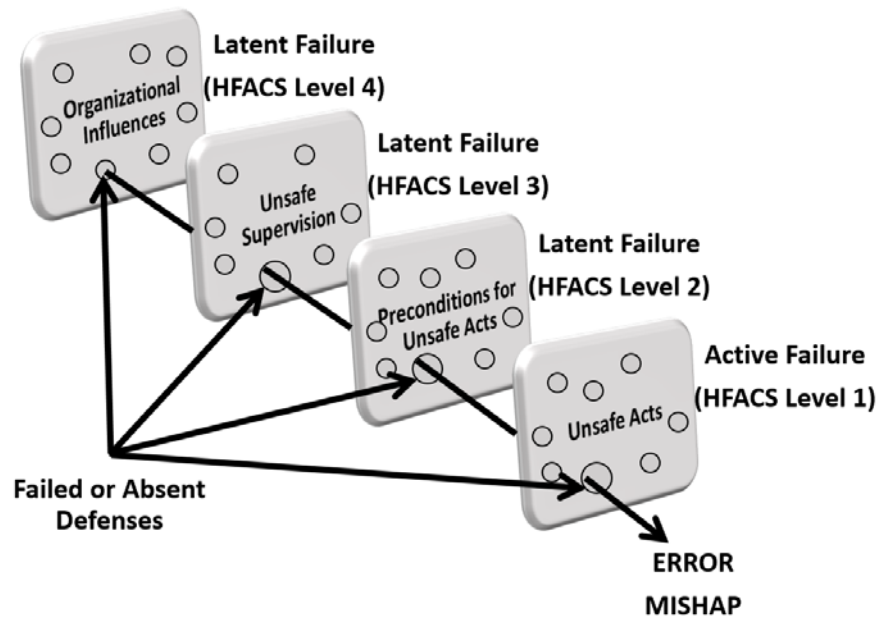
Figure 1.   Diagram of Reason's Swiss Cheese model of human error and Human Factors Analysis Classification System (HFACS)

Source: Created by author. Adapted from James Reason, *Human Error* (Cambridge, England: Cambridge University Press; 1990); Scott Shappell and Doug Wiegmann, "Applying Reason: The Human Factors Analysis and Classification System," *Human Factors and Aerospace Safety* 1 (2000): 59-86.

Dr. Scott Shappell and Dr. Doug Wiegmann developed the Human Factors Analysis and Classification System (HFACS) based off Reason's Swiss Cheese model of human error (Shappell and Wiegmann 2000). Their landmark study concluded human error was the primary cause in about 70 to 80 percent of all flight accidents in the Marine Corps and Navy (Shappell and Wiegmann 2000). In context, the researchers were concluding that variations within the organizational influences, unsafe supervision, preconditions for unsafe acts, and unsafe acts are conditions that may lead to or prevent an error. In a sense the 70-80 percent cause of all flight accidents are designs in the system that caused barriers to correct latent failures or facilitated latent failures to

become active failures that caused error (Shappell and Wiegmann 2000). In fact, in a similar study in healthcare, it is estimated that up to 80 percent of medical errors arise out of systemic factors (Reason 1995).
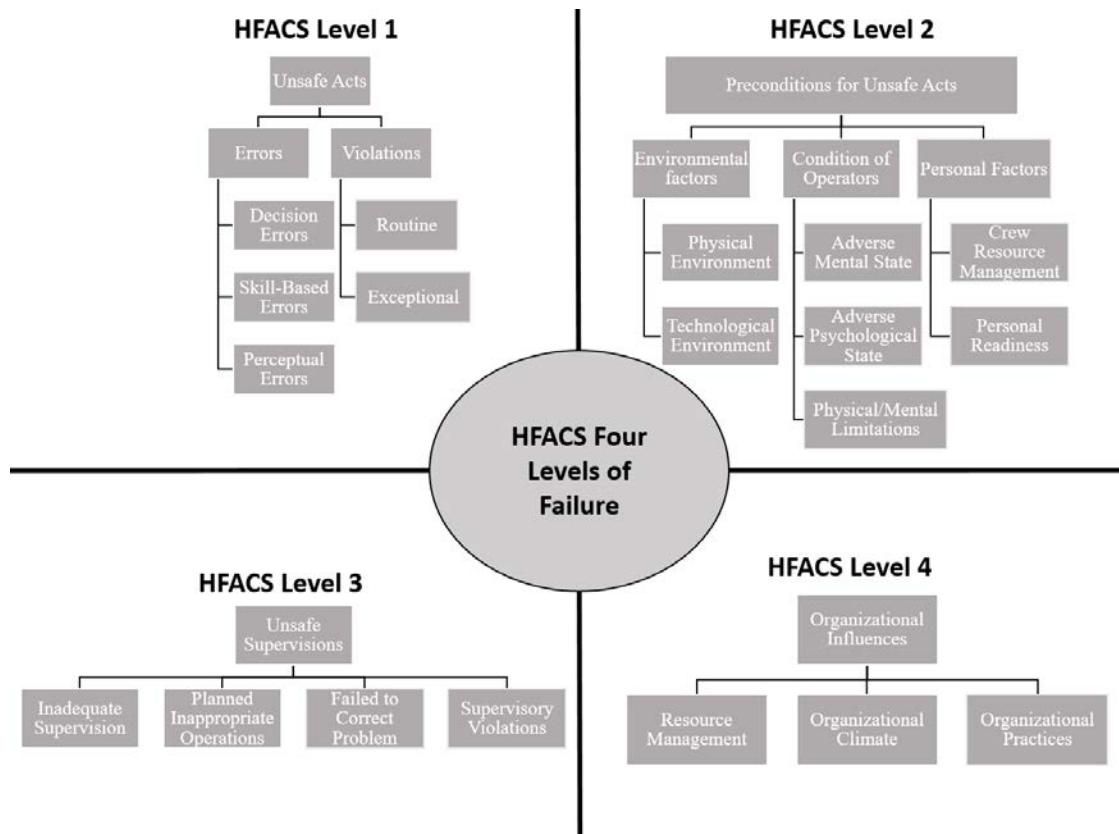
Figure 2.   Human Factors Analysis Classification System (HFACS)

Source: Created by author. Adapted from Scott Shappell and Doug Wiegmann, "Applying Reason: The Human Factors Analysis and Classification System," *Human Factors and Aerospace Safety* 1 (2000): 59-86.

Dr. Shappell and Dr. Weigmann HFACS taxonomy tool describes in detail the four levels of failure in Reason's model and defined within the model are 19 causal

categories to identify the possible human causes and from there work targeting training and prevention efforts (Shappell and Weigmann 2000).

HFACS Level One refers to unsafe acts and divided into errors and violations categories. Errors are unintentional behaviors and divided into subcategories of decision, skill based, and perceptual errors. Violations are a willful disregard of the rules and regulations and further delineated into routine and exceptional (Shappell and Weigmann 2000).

1a. Decision errors represents intentional behavior that proceeds as intended, yet the plan proves inadequate for the inappropriate for the situation (e.g., improper procedure, misdiagnosed emergency, poor decision).

1b. Skill-based errors are related to autopilot mode that occurs during the operator's routine tasks and results in an unsafe situation (e.g., omitted checklist item, poor technique, failed to prioritize attention).

1c. Perceptual errors occur when sensory input is degraded or unusual (e.g., misjudged distance, visual illusion).

1d. Routine violations are errors that tend to be habitual by nature and often tolerated by governing authority, bending the rules (e.g., driving over the speed limit 5-10 mph faster than allowed by law consistently).

1e. Exceptional violations are errors that are neither typical of the individual nor condoned by authority (e.g., isolated instance of driving 60 mph in a 20 mph zone).

HFACS Level Two focuses on preconditions for unsafe acts and divides into environmental, condition of operators, and personnel factors categories (Shappell and Weigmann 2000).

2a. Environmental factors such as physical environment refer to factors that include the operational setting and ambient environment (e.g., heat, cold, and lighting). Technological environment refers to factors that include a variety of design and automation issues (e.g., checklist layouts, automation).

2b. Condition of the operators focuses on adverse mental and psychological states and physical and mental limitations. Adverse mental state are mental conditions and factors that affect performance (e.g., complacency, get-home-itis, mental fatigue). Adverse psychological states are medical or physiological conditions that preclude safe operations (e.g., medical illness, physical fatigue). Physical and mental limitations refer to those instances when mission requirements exceed the capabilities of the individual at the controls (e.g., insufficient reaction time, visual limitation).

2c. Personnel factors includes crew resource management (CRM) and personnel readiness. CRM factors include communication, coordination, planning, and teamwork issues (e.g., failed to communicate/coordinate, failure of leadership, misinterpretation). Personal readiness factors include failures that occur when individuals fail to prepare physically or mentally for duty (e.g., excessive physical training, self-medicating, drinking alcohol while on duty).

HFACS Level Three focuses on unsafe supervisions that are inadequate, inappropriate, failed to correct the problem, and violations willfully disregarded by supervisors (Shappell and Weigmann 2000).

3a. Inadequate supervisions are failure of supervision to provide sound professional guidance and oversight (e.g., determining whether the supervision was inappropriate or did not occur at all).

3b. Planned inappropriate operation refers to performing emergency operations during normal operations (e.g., improper staffing, failure to provide correct data).

3c. Failed to correct the problem refers to those instance when deficiencies among individuals, equipment, training, or other related safety areas are known to the supervisor, yet are allowed to continue unabated (e.g., failed to correct document in error, failed to report or identify unsafe tendencies).

3d. Supervisory violations are reserved for those instances when existing rules and regulations are willfully disregarded by supervisors (e.g., authorized unnecessary hazard, failed to enforce rules and regulations).

HFACS Level four focuses on organizational influences of fallible decisions of upper-level management that directly affect supervisory practices, as well as the conditions and actions of operators (Shappell and Weigmann 2000).

4a. Resource management are corporate-level decision-making processes regarding allocation and maintenance of organizational assets (e.g., human resources, monetary, equipment/facilities, excessive cost cutting).

4b. Organizational climate is a broad class of organizational variables that influence worker performance (e.g., structure, policies, culture).

4c. Organizational processes are decisions and rules that govern the daily

activities within an organization (e.g., operations, procedures, oversight).

Reason's Swiss Cheese model and HFACS apply a comprehensive approach for

identifying and classifying human and system causes of accidents. These two models

have significantly impacted the aviation industry for decades and improved their

reliability across the board and made them HROs. The recent applications to the

healthcare industry have shown significant promise, especially in designing hospitals to

be safer. This organizational approach to decreasing error supports the thought that

"systems design should be based on an understanding of human behavior, and the nature

of the task, rather than necessarily adapting performance to suit the system" (Reason

1995).

HROs in the Military

Three researchers from the Berkley campus of the University of California were

part of the counter argument to Normal Accident Theory and created the term High

Reliability Organization. Gene Rochlin, Todd LaPorte, and Karlene Roberts created the

HRO term based on their observation of operations on aircraft carrier USS Carl Vinson

(Rochlin et al. 1987). The observations of the U.S. Navy's carrier were included in a

larger project within four major organizations: the Air Traffic Control System, Federal

Aviation Administration and the Electric Operations and Power Generation Departments

of the Pacific Gas and Electric Company (Rochlin et al. 1987).

The researchers sought to understand how these organizations operate in

extraordinary situations with technologies that can be beneficial, costly, and hazardous

and still achieve high levels of operational reliability and failure free operations in austere

20

and unexpected conditions (Rochlin et al. 1987). The aims of this study were to seek out

the conditions, to include organizational structures and mindsets that created high levels

of operational performance and reliability continuously in austere environments. The

researchers' goals were to understand what types of challenges do large high reliability

organizations confront. How do they manage to maintain an extremely low error rate

while engaged in managing often very intense activities, in which time sensitive decision

and decisive actions are often crucial (Rochlin et al. 1987)?

The project observed this high intensity operation of landing aircraft during

inclement weather that consisted of snow, ice, thunderstorms, and turbulent seas. One

observation by the researchers centered on the aircraft carrier during high phases of

operational tempo and they described it as:

> A crew of up to 3000, supporting an Air Wing of some 90 aircraft and
> another 2800 men, operated the aircraft carrier. During phases of high readiness
> (daily operations from mid-morning to mid-might), the Air Department may
> handle up to some 200 sorties per day/night, involving some 300 cycles of aircraft
> preparation, positioning, launch, and arrested landings (often at about 55 sec.
> intervals). Over 600 aircraft movements across portions of the deck are likely
> with a crunch rate, i.e., the number of times two aircraft nick each other, of about
> 1:7000 moves. At the same time, aircraft are re-fueled, serviced and ordinance
> loaded sometimes with engines still running. These periods of high performance
> run continuously for up to four weeks at a time with short break for the duration
> of a 6-8 month deployment. (Rochlin 1987)

This observation illustrated the many complex and tightly coupled systems

integrated to anticipate error and mitigate its effects. Failures within an aircraft carrier, an

electrical plant, an airport, or a nuclear plant caused by fire or other explosion could

quickly kill people, cause irreversible damage to equipment and infrastructure, and in the

nuclear areas cause major ecological and human catastrophe (Rochlin et al. 1987).

Within the projects the researchers observed that each organization had embedded a "widely dispersed network linking operating and coordinating units in a set of tightly-coupled, overlapping interdependent webs of direction, action, and feedback" (Rochlin et al. 1987). These tightly coupled systems prevented errors and allowed failures to propagate quickly to those with the most knowledge to handle them. In turn, this mitigated the failures, avoided catastrophic outcomes, and ensured the continuity to maintain high tempo operations even in unexpected situations.

<u>HRO Management Model Proposed</u>

Dr. Carolyn Libuser and Dr. Kathleen Roberts from UC Berkley developed a management model in 1995 based on an investigation of five commercial banks. The findings revealed processes that an organization should implement to maintain and maximize its reliability. The five processes by Dr. Libuser and Dr. Roberts are:

1. Process auditing: An established system for ongoing checks and balances designed to spot expected as well as unexpected safety problems. Safety drills and equipment testing are included. Follow-ups on problems revealed in previous audits are critical (Roberts 2003).

2. Appropriate reward systems: The payoff an individual or organization realizes for behaving one way or another. Rewards have powerful influences on individual, organizational, and inter-organizational behavior (Roberts 2003).

3. Avoiding quality degradation: Comparing the quality of the system to a referent generally regarded as the standard for quality in the industry and insuring similar quality (Roberts 2003).

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4. Risk perception**:** This includes two elements: (a) whether there is knowledge that risk exists, and (b) if there is knowledge that risk exists, acknowledging it, and taking appropriate steps to mitigate or minimize it (Roberts 2003).

5. Command and control: This includes five processes: (a) decision migration to the person with the most expertise to make the decision, (b) redundancy in people and/or hardware, (c) senior managers who see the big picture, (d) formal rules and procedures, and (e) training-training-training (Roberts 2003).

These five processes created the starting point of a management model for HROs.

<u>Principles of HRO established-Collective Mindfulness</u>

In 1995, a group of professors from University of Michigan established HRO principles. Karl E. Weick and Kathleen Sutcliffe, professors from the University of Michigan, continued to expound on HRO research by further analyzing the organizational perspective of decreasing error and maintaining high reliability (Roberts 2003).

Weick and Sutcliffe research revealed that organizations must continually reinvent themselves to maintain success. The reinvention centered on creating cognitive infrastructure to support a collective mindfulness to decrease error and maintain high reliability without decreasing efficiency and increasing costs (Roberts 2003). In 2001, 2007, and 2015, Weick and Sutcliffe further established the traits of HROs into principles in their books titled *Managing the Unexpected* with subtitles: *Assuring High Performance in an Age of Complexity* (Weick and Sutcliffe 2001), *Resilient Performance in an Age of Uncertainty* (Weick and Sutcliffe 2007) and finally *Sustained Performance in a Complex World* (Weick and Sutcliffe 2015).

Interwoven throughout the books is the common theme of how these HRO principles create an environment of collective mindfulness that can anticipate, contain, and rebound from errors during high tempo operations in austere environments while sustaining high reliability. The books provide case examples of major organizations that have embedded these principles and have outcomes that have significantly decreased error and maintained high reliability. The books also provide case examples of major organizations that have not embedded these principles and have had catastrophic failure on multiple levels that have led to loss of life, infrastructure, economic, and environmental calamities.
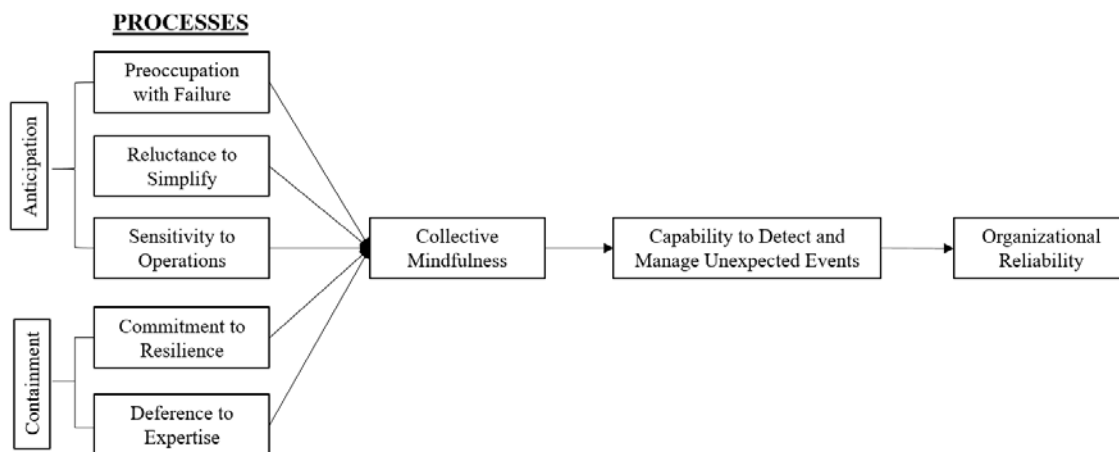
Figure 3.   Conceptual model for a mindful infrastructure for high reliability

Source: Created by author. Adapted from Karl Weick and Kathleen Sutcliffe, *Managing the Unexpected: Assuring High Performance in an Age of Complexity* (San Francisco, CA: Jossey-Bass, 2001).

Weick and Sutcliffe principles for HRO are:

1. Preoccupation with failure (rather than successes): HROs avoid disasters due to being preoccupied with their failures, large and small. They treat any lapse as a symptom that something is wrong with the system, something that could have severe consequences if separate small errors happen to coincide at one awful moment. For example, an inappropriate drug calculation of a certain medication that left a patient incapacitated or caused death (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

2. Reluctance to simplify interpretations: HROs manage for the unexpected by being reluctant to accept simplifications. HROs take deliberate steps to simplify less and see more with the knowledge that the world they face is complex, unstable, unknowable, and unpredictable, they position themselves to see as much as possible. The staff is encouraged to become people who have diverse experiences, and skepticism toward received wisdom. In addition, this skepticism works to cross borders and builds relationships to improve reliability (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

3. Sensitivity to operations: An additional characteristic of HROs is their ability to point to their ongoing concern with the unexpected. HROs distinguish themselves by being attentive to the front line. The big picture in HROs is less strategic and more situational than other organizations. HROs are aware of the close tie between sensitivity to operations and sensitivity to relationships (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

4. Commitment to resilience: HROs understand that no system is perfect. HROs develop capabilities to detect, contain, and rebound back from inevitable errors that are part of an indeterminate world. The signature trait is not that an HRO is error-free, but that the errors do not disable it (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

5. Deference to expertise: Decisions are made on the front line, and authority migrates to the people with the most expertise, regardless of their rank. The pattern of decisions migrating to expertise is found in flight operations on aircraft carriers, where uniqueness coupled with the need for accurate decisions lead to decisions that search for the expert and migrate around the organization (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

6. Mindful Awareness and Anticipation of the Unexpected: The enhanced ability by HROs to use the first three of the five processes: preoccupation with failure, reluctance to simplify interpretations, and sensitivity to operations to become aware of unanticipated events and see them earlier enough to act before problems become severe (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

7. Mindful Containment of the Unexpected: This is a combined approach by HROs to use commitment to resilience and deference to expertise to contain and rebound back from problems mindfully when precautions fail and unexpected events escalate into a crisis (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

8. Collective Mindfulness: The five processes above produce a collective state of mindfulness. This in turn, promotes a rich awareness of discriminatory detail and an enhanced ability to discover and correct errors that could escalate into a crisis (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

<u>Concept of Mindfulness</u>

Ellen J. Langer is one of the most influential pioneers who brought the concepts of mindfulness and mindlessness to the forefront and its impact on error (Langer 2000). Dr. Langer pioneering studies focused into three major categories: health, business, and education. Mindfulness is described as a heightened state of involvement and wakefulness or being in the present (Langer 2000). Dr. Langley argues that this "heightened state of involvement" enables the individual to develop: "(1) a greater sensitivity to one's environment, (2) more openness to new information, (3) the creation of new categories for structuring perception, and (4) enhanced awareness of multiple perspectives in problem solving (Langley 2000)." Mindful individuals are able to follow the processes that lead to an outcome, instead of focused on the outcome. This allows for closer scrutiny of the processes and ability to catch errors before they lead to unexpected and catastrophic events (Langley 2000).

These individual states of mindfulness further integrate within collective mindfulness concepts as described above at the unit or organization level (Weick and Sutcliffe 1999). In relation to HROs, this enriched mindful individual promotes the collective mindfulness of HROs to anticipate potentials for catastrophe and facilitates the construction, discovery, and correction of unexpected events capable of escalation (Weick and Sutcliffe 1999).

Many people often compare mindfulness with situational awareness but there is a distinct difference described by Weick and Sutcliffe:

> Mindfulness is different from situational awareness in the sense that it involves the combination of ongoing scrutiny of existing expectations, continuous refinement and differentiation of expectations based on newer experiences, willingness and capability to invent new expectations that make sense of unprecedented events, a more nuanced appreciation of context that improve foresight and current functioning. (Weick and Sutcliff 2007)

Mindfulness is less about decision-making and more about inquiry and interpretation and taking action. These stable but diverse quality cognitive processes interrelate in the service of the discovery and correction of errors and counters the tendency to normalize (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

Organizing for High Reliability

The concepts from HRO models and principles have formed the theoretical frameworks and processes to organize for high reliability. Many researchers argue that studying organizational components for HROs themselves "provide a window on a distinctive set of processes that foster effectiveness under trying conditions" (Weick and Sutcliffe 1999). Implementing these processes and frameworks to organize for high reliability have enabled organizations to become HROs by organizing themselves to sustain high-risk, high-tempo near-perfect operations, generally free of error and catastrophic events (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

Organizing for high reliability to manage the complex and tight coupling comes from the cognitive infrastructure to facilitate mindful organizing and set the conditions

for collective mindfulness. As described above the principles within collective mindfulness: preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and deference to expertise allow processes to be organized mindfully and collectively enhances an organization's ability to detect and manage unexpected events and minimize errors (Weick and Sutcliffe 1999).

<center>HROs in Health Care</center>

The healthcare industry is relatively new to implementing HRO when compared to major industries within electric, nuclear, and the Navy who have had decades of lessons learned and research to improve their high reliability systems. In 1989, elements of Dr. Libuser and Dr. Roberts reliability management model reinvigorated a pediatric intensive care unit (PICU) by implementing elements of HRO to reduce error (Roberts 2003). For 11 years, the PICU operated as an HRO. Despite experiencing increased census and acuity levels, the mortality and consequential events diminished. In 1996, the PICU actually had no adverse events in patient handoffs and experienced a low error rate when compared to other PICUs (Roberts 2005). However, change occurred after the departing of the two attending physicians who advocated for elements of HROs. Their replacements had no knowledge or understanding of HROs. These physicians in turned utilized a medical model centered on evidence-based medicine and in turn the PICU experienced increased readmission rates within 48 hours, hostile work environment, deteriorating patient safety climate, and increased error rate (Roberts 2005).

In 1994, anesthesia became one of the first medical specialties to publish in medical literature the connection of how human factors and complexities of the healthcare systems can lead to error (Roberts 2003). Dr. Gaba, an anesthesiologist, and

<center>29</center>

his team identified how production pressure and prioritization may influence anesthesia providers to deviate from standard safety precautions and policies and commit unintentional errors in judgment as well as performance (Gaba 1994).

In 1995, The Department of Defense (DOD) also began to start a movement toward patient safety and implemented elements of HRO. The primary focus was on team training to improve communication, and reduce medical errors. The multi-year research study conducted by the DOD introduced formal teamwork training based on aviation Crew Resource Management (CRM) training concepts to healthcare named MedTeams (Agency for Healthcare Research and Quality 2015). This study began with a retrospective review of an Emergency Department that revealed 43 percent of errors resulted from problems with team coordination, primarily communication. In fact in almost all cases, it stated that "an effective team structure and caregivers trained in team behavior would have mitigated or prevented 79 percent of the identified failure" (Agency for Healthcare Research and Quality 2015). MedTeams was offered as a solution that could possibly decrease medical errors.

Four years later in 1999 the Institute of Medicine published the landmark report *To Err is Human* that concluded that preventable medical errors caused between 44,000 and 98,000 deaths annually, and costs our nation approximately $38 billion each year, $17 billion of those costs are associated with preventable human error (Kohn 1999). This report drew widespread attention and efforts from the public, government, media, health care professions, and other professionals to work on developing solutions in order to decrease medical errors, save lives, and decrease costs.

Several initiatives focused on adoption of human factors training, CRM for

improving medical team performance, and increased reporting of medical errors. In 2001,

the DOD Institute for Patient Safety Program mandated that MedTeams training would

be required in military health organizations (Agency for Healthcare Research and Quality

2015). Other strategic initiatives included further collaboration between the DOD,

AHRQ, and the Joint Commission to develop National Patient Safety Goals focused on

improving communication among the health care team (Agency for Healthcare Research

and Quality 2015). In 2004, The 100K Lives Campaign was a successful initiative for

change to improve patient safety and prevent medical errors and avoidable deaths.

Thousands of hospitals across the U.S. committed and implemented evidence based

changes in patient care to prevent avoidable deaths and in 2006, the campaign

accomplished saving over 100,000 lives (Agency for Healthcare Research and Quality

2015).

Additional initiatives focused on establishing voluntary and confidential reporting

of medical errors to patient safety organizations. An official healthcare version of CRM

named Team Strategies and Tools to Enhance Performance and Patient Safety

(TeamSTEPPS) was created to decrease preventable error. TeamSTEPPS was

implemented across the nation's healthcare institutions with tools focused on building:

communication, situation monitoring, leadership, mutual support, and team structure

(Agency for Healthcare Research and Quality 2015). In April 2011, an article in *Health

Affairs* identified more than 1.5 million preventable errors occurs annually in the U.S.

healthcare system solidifying the need for programs like TeamSTEPPS to improve

reliability (Bos et al. 2011).

With the focus on prevention and increasing the ability to recognize and intervene during the first signs of a patient decline, it would seem that the healthcare system was reversing the tide against losing life from preventable medical errors. However, in September 2013, the *Journal of Patient Safety*, released an even higher statistic of 440,000 deaths annually were caused by preventable harm (James 2013). This shocking statistic revealed that the healthcare system has been slow to adopt HRO concepts and the implemented initiatives were not working quickly to decrease deaths caused by preventable error. It would seem that no specific solution existed that would solve this healthcare crisis.

It is important to mention that there is no well-documented evidence of hospitals, which have transitioned from a low-reliability into a high-reliability organization and sustained that accomplishment. However, it is important to appreciate that major organizations that implemented HRO concepts have been able to validate a significant decrease in medical errors, decreased associated costs to medical care, and improved healthcare delivery system (Chassin 2013).

<u>The MHS in the Battlefield</u>

It is important to note in the recent *MHS Review* conducted in 2014, did not go into detail of challenges the MHS faces when in deployed environments. It is likely that the six, independent and esteemed national experts in patient safety and quality who conducted the review could not truly have a basis or an understanding of how to deliver healthcare in the battlefield and could not accurately provide concise recommendations on improving reliability. In addition, it appears the majority of issues dealing with

preventable error within the MHS are compounded in garrison type settings (U.S. Department of Defense 2014).

There are many challenges and differences in delivering healthcare in garrison and deployed environments. These differences have been studied and presented in various ways to highlight the challenges of maintaining the same standard in deployed environments where mass casualties can quickly overrun scant resources of staff and supplies. Despite those challenges, the MHS has been able to maintain many aspects of high reliability in delivering highly effective healthcare on the battlefield with at times an estimated survivability rate of 92 percent and even higher rate of 98 percent if casualties are brought to the combat hospital alive (Joint Theatre Trauma System 2014).

Several research articles have touted the high survivability rate in combat environments that the MHS has been able to maintain despite the limited resources. It is important to understand that although this is a high survivability rate, it does not take into consideration of how many preventable errors or errors occurred on the battlefield and how many of them led to harm. The challenge has been how to accurately collect data and analyze it to create standards to implement when the environment may frequently change due to such considerations: the enemy threat, having appropriate medical staff, medical supplies, and other resources available, battle fatigue, challenges in evacuating and doing surgery under enemy fire to name a few.

These considerations have not been studied thoroughly in the literature and unlikely to be studied in depth due to the considerable challenges faced when collecting this type of data in these austere dangerous conditions that frequently change. However,

despite these challenges, there has been significant research collected by the Joint Theatre Trauma System (JTTS) that have directly affected survivability rates.

Joint Theater Trauma System

The JTTS has the purpose to improve outcomes of casualties on the battlefield (Eastridge 2009). Based off U.S. civilian trauma systems, the JTTS provides concurrent and continuous performance improvement and evidence-based practice in combat casualty care in the theaters of Iraq and Afghanistan. The JTTS through the Joint Theatre Trauma Registry (JTTR) has created one of the most successful robust process improvement programs that have directly impacted the battlefield. As of January 22, 2014, it has 128,267 records on file (Joint Theatre Trauma Registry 2014). The data collected from the trauma registry is consistently analyzed to look for ways to organize and coordinate efforts to deliver high quality care and improve patient transitions between phases of care. The JTTR impact has been published and measured in several peer review journals.

The JTTR established standards and clinical practice guidelines (CPG) which were initially absent in the beginning phases of the Iraq and Afghanistan Wars. There were variances of standards and challenges with enroute care that at times subjected the casualties to higher risk. With the implementation of CPGs from the JTTR improved survival after battlefield injuries and set the standard for trauma care on the modern battlefield (Eastridge et al. 2009). The JTTR disseminated 27 CPGs and three of them significantly decreased mortality rates in burn resuscitation, hypothermia, and complications arising from massive transfusion (Eastridge et al. 2009).

However, despite implementation of evidence based standards and CPGs, there were still challenges with following them in combat environments. This has been a point of contention among several recognized experts of how to ensure and maintain quality management on the battlefield and if it is even desirable to do so (Cohen 2005).

<div align="center">Quality Management on the Battlefield</div>

Since before the Institute of Medicine landmark report in 1999 to *Err is Human*, the MHS has been consistently challenging with how to improve and maintain clinical quality management (CQM) on the battlefield to decrease medical error (Cohen 2005). CQM is a relatively new model designed for healthcare to provide a multidisciplinary, systematic, and organized approach to healthcare and services to enhance quality (DeLorenzo and Pfaff 2011). Experts argue that CQM can have detrimental effects on the effectiveness of the MHS in combat zones if it is applied rigidly to the battlefield that is in distant, austere, and complex environment of care (DeLorenzo 2011).

In a 2005 article, COL David J. Cohen saw the benefits that could come from application of CQM in setting the stage for the MHS to develop error-reporting systems, identification of standards and benchmarks to measure, and possible changes to the military Table of Organization and Equipment (TOE) to accommodate the resources to support this concept (Cohen 2005). COL Cohen agreed that certain quality processes could be applied to any military setting to include garrison and deployed environments across the echelons of care but cautioned that the standard measures should be flexible to fit within those environments. The environments subject to requiring flexibility is deployed environments that are often austere, dangerous, and when resources are limited (Cohen 2005).

In 2011, an article by COL Robert A. De Lorenzo and COL James A. Pfaff seemed to agree with the concerns of COL Cohen of implementing CQM on the battlefield (DeLorenzo and Pfaff 2011). An interesting point of concern is how much CQM to apply in an immature and mature theatre. The recent two wars in which we have been involved have matured and by some accounts, experts see the introduction of combat zone CQM as a natural extension maturation that ultimately will evolve into the fixed MTFs in Germany and Korea that provide peacetime care (Budinger 2008). The ongoing concerns the authors highlight of implementation of CQM is that it should be flexible to fit the conditions on the ground. In some locations, the amount of paperwork involved in CQM outnumbers the amount of patients seen in a deployed environment (DeLorenzo and Pfaff 2011). This is obviously a concern when layers of bureaucracy are added into an already challenging deployed environment.

Despite the concerns with implementing initiatives like CQM within the MHS in combat zones, there is now an overwhelming emphasis and effort to improve reliability and decrease preventable error. Recent initiatives focused within building high reliability in the MHS to decrease preventable error and adverse events could resolve the concerns the authors have about CQM implementation. Application of high reliability may offer a way to improve quality and at the same time have less detrimental effects of the effectiveness of the MHS across the full spectrum of operations across the continuum of care from point of injury to care in the United States (U.S. Department of Defense 2014).

High Reliability in the Military Health System

It is worth acknowledging again that the MHS has undergone a recent review of its delivery of healthcare. This landmark review was the first of its kind mandated by the

Secretary of Defense (SECDEF). Based on the findings of the *MHS Review*, the SECDEF ordered the MHS to improve primarily in access to medical care, quality of health care, and safety across its healthcare system. This report primarily revealed the variability in benchmarks when compared to civilian counterparts (U.S. Department of Defense 2014).The *MHS Review* shaped the framework for the MHS to combine the concepts of an integrated health care system with the principles of HRO (U.S. Department of Defense 2014).

Since the *MHS Review*, great efforts in research and promotion of integration of HRO concepts have been implemented across the Armed Forces. Recently papers have been published with the intent to strategically align each sister service towards the journey of organizing for high reliability and becoming a HRO. Papers such as the *MHS Review*, *MHS Leadership Engagement Toolkit*, and *HRO Taskforce Resource Guide* have offered the members of the MHS working at strategic, operational, and tactical levels a path instituting the journey to HRO and accomplishing it (U.S. Department of Defense 2014, U.S Department of Defense 2015, U.S. Department of Defense 2016).

This author analyzed the data gathered from the recent five-year literature review and aligned it within the current strategy of the MHS in the analysis portion of Chapter 4. In particular, the recent strategic spotlight created by Army Medicine that aligns within the MHS overarching theme of each sister service undergo not only their journey of HRO but integration across the MHS enterprise (U.S. Department of the Army Medical Department 2015).
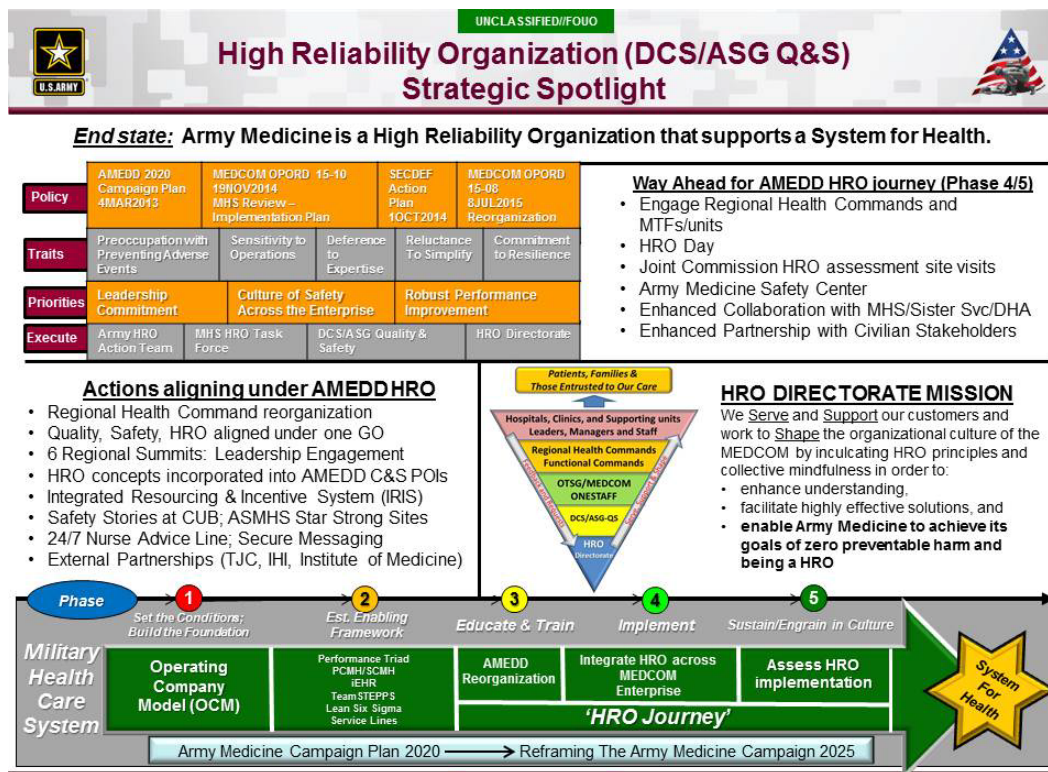
Figure 4.   AMEDD High Reliability Organization Strategic Spotlight

Source: AMEDD High Reliability Milsuite webpage, accessed February 1, 2016, https://www.milsuite.mil/book/groups/ameddcsjbsa-hro-patient-safety-short-course.

Summary

For several decades, HROs have displayed and sustained optimal levels of operations virtually free of preventable error and avoided catastrophic failure. Healthcare has been slow to adopt and implement HRO concepts despite the increasing body of literature that validates results of implementing these tools decreases preventable error and increases reliability (Chassin 2013).

This review of literature of HROs revealed the founding concepts and principles that have made HROs successful. Organizations such as: nuclear power-generation

plants, naval aircraft carriers, chemical production plants, offshore drilling rigs, air traffic control systems, incident command teams, wildland firefighting crews, hospital emergency room and intensive care units, and investment banks that have implemented HRO concepts have shown a significant decrease in preventable error while maintaining high tempo operations (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

In chapter 4, the author will further analyze the recent articles focused on HRO concepts and seek their applicability to the Military Health System. These recently published articles within the last five years have provided reviews and research of how HRO concepts have significantly caused a decrease in preventable error in several medical specialties, units, hospitals, and healthcare systems. The majority of articles reviewed organized their findings generally within HRO principles, and occasionally with additional topics such recognizing human factors that create error, tools to create a culture of safety, leadership traits needed within HROs, and a robust process improvement that further supports the healthcare system in decreasing error and increasing reliability. The articles present various perspectives and specialties on how to improve the healthcare delivery system to decrease preventable error and the harm caused by errors.

CHAPTER 3

RESEARCH METHODOLOGY

Methodology

This research used a systematic review of the literature in PubMed to find

relevant articles focusing on High Reliability Organizations in hospitals. PubMed is a

service of the U.S. National Library of Medicine that provides validated peer-reviewed

free access to indexed abstracts to medical, nursing, dental, veterinary, health care, and

preclinical sciences journal articles (U.S. National Library of Medicine 2016). PubMed

Papers were deemed appropriate for inclusion if they focused primarily on the topic of

HROs and were published in peer-reviewed journals. Both theoretical, discussion and

empirical papers were included as well as book chapters that explicitly focused on HROs.

To support the analysis, a small number of regulatory documents that referenced HROs

or related concepts are included that was not in the systematic review of the literature. In

addition, articles focused on combat casualty care such as those from the Joint Trauma

System (JTS) initiatives and the US AMEDD Lessons Learned site were also included.

I analyzed the most recent articles in PubMed and developed tables to display the

evidence of how other hospitals using HRO concepts decreased error. I used the

following terms during my search in PubMed: "High Reliability Organization,"

"Hospital," "Error*." Entering the character "*" signals the PubMed search engine to

look for all forms of the word "error". The filters I placed on the search engine: "English

language," "5 years." Journal categories included core clinical journals, dental journals,

MEDLINE, and nursing journals. This produced a search engine result of 70 articles. I

then analyzed each abstract of the articles and deleted them based on content that did not

relate to HROs. The majority of the articles deleted had the term "reliability" that focused

on the accuracy of medical instrumentation devices. Articles of medical instrumentation

devices were included that incorporated human error application and when a medical

device fails during a procedure. The remaining 34 articles were included in to the final

review.
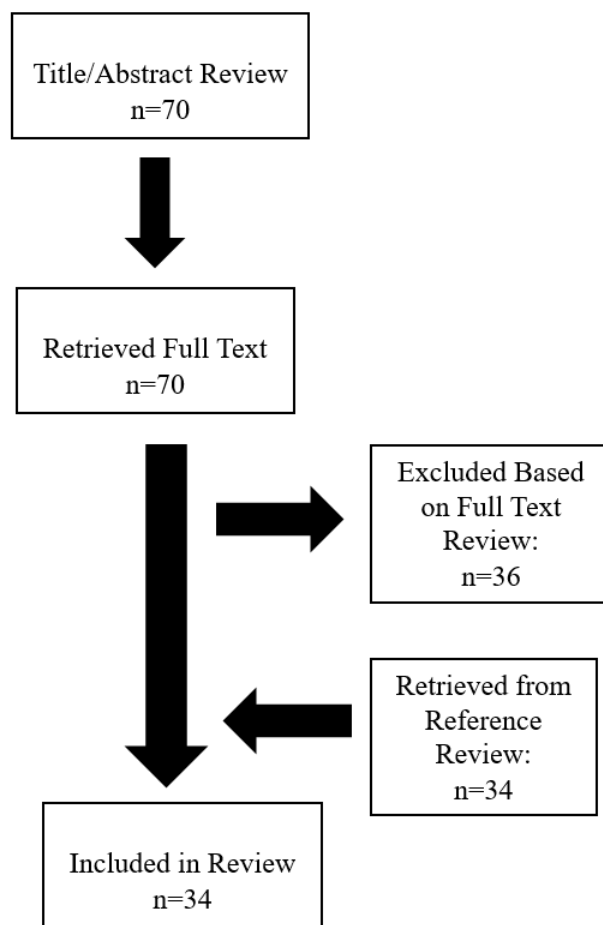
Figure 5.   Consort diagram and search strategy from review of literature

Source: Created by author.

The 34 articles left for the review were then assessed by using a methodological quality modified 7-level rating scheme for evidence hierarchy (Melnyk and Fineour-Overholt 2005). This is a validated tool and is used often to assess and rate the level of evidence within healthcare articles.

Table 1.   Rating system for the hierarchy of evidence

Evidence Rating	Evaluation Criteria
Level I	Evidence from a systematic review or meta-analysis of all relevant randomized controlled trials (RCTs), or evidence-based clinical practice guidelines based on systematic reviews of RCTs
Level II	Evidence obtained from at least one well-designed RCT
Level III	Evidence obtained from well-designed controlled trials without randomization
Level IV	Evidence from well-designed case control and cohort studies
Level V	Evidence from systematic reviews of descriptive and qualitative studies
Level VI	Evidence from a single descriptive or qualitative study
Level VII	Evidence from the opinion of authorities and/or reports of expert committees

Source: Created by author based on modified evidence tables by Bernadette Melnyk and Evelyn Fineour-Overholt, *Evidence-Based Practice in Nursing and Healthcare: A Guide to Best Practice* (Philadelphia, PA: Lippincott Williams and Wilkins, 2005).

The John Hopkins Nursing Quality of Evidence Appraisal was used to evaluate each article for quality of research and non-research evidence (Newhouse 2007). This is a validated tool used to assess and rate the quality of evidence within healthcare articles. Based on both tools to assess the level of evidence and quality of evidence, I created a detailed evidence table to synthesize the findings from each included article within the five-year search results in PubMed located in Appendix A titled "Evidence Tables from Articles Included in Literature Review."

Table 2.   Quality of Evidence Appraisal

Grade	Nomenclature	Definition for research evidence	Non-research evidence
A	High	Consistent results, sufficient sample size, adequate control, and definitive conclusions; consistent recommendations based on extensive literature review that includes thoughtful reference to scientific evidence.	Expertise is clearly evident
B	Good	Reasonably consistent results, sufficient sample size, some control, and fairly definitive conclusions; reasonably consistent recommendations based on fairly comprehensive literature review that includes some reference to scientific evidence.	Expertise appears to be credible
C	Low/major flaw	Little evidence with inconsistent results, insufficient sample size, conclusions cannot be drawn.	Expertise is not discernable or is dubious

Source: Created by author adapted from Robin Newhouse, Sandra Dearholt, Stephanie Poe, Linda Pugh, and Kathleen White, *Johns Hopkins Nursing Evidence Based Practice Model and Guidelines* (Indianapolis, IN: Sigma Theta Tau International, 2007).

Based on the evidence table I created another table focused on HRO concepts and display tools that can be used to decrease preventable error and increase reliability. This table is focused within the five principles of HRO: preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and dereference to expertise. The HRO principles supports the healthcare system in decreasing preventable errors and increases reliability. Additionally, I address identified gaps in using HRO tools in deployed combat environments.

In the analysis conclusion, I recommend realistic expectations regarding HRO implementations in deployed combat environments. I include possible solutions that are suitable, feasible, and acceptable based on those that meet criteria as recommendations. In addition, I propose the way ahead through Doctrine, Organizational, Training, Material, Leadership and Education, Personnel and Facilities (DOTMLPF) and policies.

Criteria used to assess suitable, feasible, acceptable are based upon, the 2011 Joint Publication 5-0 *Joint Operation Planning* and the 2012 Army Doctrine Reference Publication 5-0 *The Operations Process* (U.S. Department of Defense 2012; U.S. Department of the Army 2012). Suitability is the effectiveness of a solution that can accomplish the mission across a wide array of foreseeable and unforeseeable environments. Feasibility assesses a course of action in its ability to accomplish the mission within the established time, space, and resource limitations. Acceptability refers to whether the course of action balances costs and risks with the advantage gained and fit within the profession current norms, tradition, and culture (U.S. Department of Defense 2011; U.S. Department of the Army 2012).

CHAPTER 4

ANALYSIS

Why didn't I know?
Why didn't my advisors know?
Why wasn't I told?
Why didn't I ask?

— Weick, Karl and Kathleen Sutcliffe,
Managing the Unexpected: Assuring High Performance in an Age of Complexity

Introduction

These questions were constantly asked by Winston Churchill after a disruptive

event happened during World War II (Weick and Sutcliffe 2007). He asked these

questions after learning that Singapore was significantly susceptible to a Japanese

invasion and that there was little that he and others could do to stop this catastrophic

event. These questions became a standard for him to consistently consciously audit and

analyze what conditions may lead to failure, how to minimize it and contain the impact if

it occurred (Weick and Sutcliffe 2007).

The purpose of this analysis is to further delineate findings from the recent five-

year literature review of HRO tools and answer the primary question: What HRO tools

can be used by the Military Healthcare System to decrease preventable error in deployed

environments? In addition, the secondary research questions:

1. What HRO strategies can be used to decrease preventable error in deployed

environments?

2. What HRO tools can we use to measure preventable error in deployed

environments?

3. What challenges and opportunities exist to implementing HRO tools in deployed environments?

Analysis of a recent five-year literature review

For the purposes of analyzing the five-year literature review, this author built an evidence table and placed it in Appendix A entitled *Evidence Table from Articles Included in the Literature Review*. Articles are arranged within the five principles of HRO and numbered with superscripts, which correspond to the numbered table at Appendix A for reference.

From the majority of articles read during the five-year literature review, the authors of the healthcare articles organized their topics within the five principles of HRO. Their intent was to display how their initiatives when organized within HRO concepts created the conditions to prevent errors and contain events that may lead to catastrophic harm or failure. As one can conclude, HRO concepts and application to various organizations have evolved over time. These HRO concepts recently have been implemented in various healthcare institutions to include in various countries around the globe. Five of the 34 articles that met the inclusion criteria came from the countries of the United Kingdom, Japan, Canada, Belgium, and Palestine. These articles were included to provide additional perspectives of how HRO concepts in healthcare are showing statistical outcomes in decreasing preventable error across the globe.

Preoccupation with Failure

Articles related to preoccupation with failure included broad topics such as assessment, error prevention tools and reporting systems, standardization, simulation, and

training as tools to learn from near misses and errors. Assessing triggers that may cause latent and active failure have been shown to increase reliability by understanding the factors that led up to it (Durani et al. 2013; Larson et al. 2015). Understanding and addressing the perceptions of elements that may lead to failure such as human factors, medical, material, equipment, facility design, and systems sets the conditions to thoroughly examine the processes and create solutions to prevent them (Brennan et al. 2015; Durani et al. 2013; Larson et al. 2015; Sutton et al. 2013; Wright et al. 2015).

Error prevention tools such as the Failure Mode and Effect Analysis (FMEA) allows healthcare professionals to do a prospective risk assessment to see what complex process or technology might fail once implemented, the impacts of that failure and identifying ways to mitigate the risk (Dean et al. 2012; Hillard et al. 2012; Lyren et al. 2015). Setting up an Error Prevention task force and Adverse Drug Prevention Bundles has been shown to not only decrease error but also have shown savings in millions of dollars associated with harm caused by error (Brilli et al. 2013; Miguel et al. 2015). These initiatives in hospitals have exhibited an 83 percent reduction in their serious safety events (Brilli et al. 2013). Aviation black box is often used to capture information during a flight that is then reviewed to investigate near misses or errors that led to an aviation accident (Bowermaster et al. 2015). A pediatric cardiac surgery team applied the "black box" concept of recording and captured near misses or errors in 50 percent of their operative procedures. This process allowed the team to systematically identify the recurrent patterns that led to near misses and error to include categorizing them into human, equipment, and system failures. This prompted substantial change in processes, within the microsystem, and across their healthcare system (Bowermaster et al. 2015).

A significant number of the articles supported the development of Error Report Systems that provides real time and situation awareness of all error and potential for error (Bondrant et al. 2015; Hershey 2015; Ito et al. 2011; Milne et al. 2013; Patterson et al. 2013). These systems should share at a minimum adverse events and near misses that led or contributed to error. Most recently the utility of the reporting systems are considered cumbersome and not user friendly (Itri et al. 2012; Lyren et al. 2015; Phelan et al. 2011; Verelst et al. 2012). In order for these reporting systems to be efficient and save lives they must have processes that expedite easy reporting of near misses, errors, and in addition rapid evaluation of clinical deteriorations (Benning et al. 2011; Zaheer et al. 2015). Before an error reaches a patient, encouraging and rewarding near misses by peers and leadership have shown a significant impact in decreasing preventable error (Chassin 2013; Sheridan-Leos 2014).

Standardization has often been used as a strategy to decrease error in industries and recently in healthcare. One such strategy that showed statistical significant once implemented was the concept of a tackle box to standardize in a Connecticut hospital (Allen et al. 2014). Prior to standardizing their coronary team experienced an average 60 percent compliance in door-to-balloon metric. This compliance rate led to increased mortality and harm to the patients requiring coronary artery catheter intervention. Once the tackle box was implemented, the team decreased their time to 46.5 minutes, significantly lower than the 90-minute time and in addition they were far below state and national times (Allen et al. 2014). This concept of the checklist and the tackle box with seven essential items created a mindful approach to decreasing error and saved countless lives (Sanchez et al. 2012).

It is estimated that 1.6 million handovers in healthcare occur in the U.S. each year (Robertson et al. 2014). During a hospitalization, a patient will experience up to 24 handovers of care and be subjected to an estimated 13 percent error rate associated with additional risks from the handover (Robertson et al. 2014). It is largely disputed that the transfer of information is what subjects the handover to additional risks. These risks will continue to plague the handovers in healthcare as long as there is ambiguity and no standardization. The articles supported a need to develop a taxonomy to describe classifying handovers, improvement methods, and types of outcome (Robertson et al. 2014).

Simulation training has long been used to train teams to become high performing. Another layer of simulation is "in situ" simulation. This particular type of simulation is a team-based training technique that is conducted on an actual patient care unit, utilizing the actual members of the healthcare team to include their equipment and resources (Morrison et al. 2011; Wheeler et al. 2013). In situ simulation has supported units in identifying the latent failures or latent conditions that may lead to error. In particular, providing in situ simulation on how latent errors and small events lead to major errors and events has created high performing teams. These teams readily treat near misses and reveal potential dangers to the patient and healthcare system (Morrison et al. 2011; Wheeler et al. 2013).

Table 3.   Preoccupation with failure

PREOCCUPATION WITH FAILURE
• Address perception of elements that may lead to failure[18-19, 22]
• Adverse Drug Prevention Bundles[1]
• Assess triggers that may cause latent/active failure[18-19]
• Aviation black box principles to track failures[3]
• Checklists[12]
• Develop ways to standardize[4]
• Encourage and reward near miss reporting [13, 16]
• Error Prevention task force[1, 32]
• Expedited and easy reporting mechanism for near miss, clinical deterioration [20, 26]
• In situ simulation to identify latent errors[14]
• Real time/Situation awareness of all error and potential for error[5-6, 15, 30, 34]
• Share adverse events/near misses[7, 8, 24, 31]
• Standardized handover that poses question to support accurate transfer of information[17]
• Training on small events that lead to major events[21]
• Understanding multiple facets of various factors (human, medical, material, equipment, facilities, systems) that lead to error[11, 27]
• Utilize the Failure Mode Effect Analysis to prospectively look for ways to prevent risk, and identify low level errors[10, 24-25]

Source: Created by author.

Reluctance to Simplify

Articles that addressed reluctance to simplify contained topics of doing additional

assessments, understanding of error, performing frequent audits, root cause analysis,

surveys, and development of practices and procedures to decrease error. These articles

focused on tools that support an organizations effort to avoid simplifying processes, by

supporting the concept of promoting divergent views, and valued skepticism to

counteract the complacency that redundant systems may adopt (Weick et al. 1999).

In healthcare there seems to be no limit of interruptions. Assessment of

interruptions and finding ways to limit them can support decreasing error. Emergency

Departments (ED) and other critical care areas are prone with interruptions that could

lead to hazardous outcomes in patient care (Morrison et al. 2011). In one ED study, emergency physicians were interrupted an average of 10 times per hour when interacting or conducting interventions on patients and nurses were interrupted even more (Morrison et al. 2011). These interruptions have been shown to contribute to medical error and have increased stress and reduced efficiency among physicians and the healthcare team (Morrison et al. 2011).

When errors occur, there is often a human and system component to it. In fact, 80 percent of medical errors arise out of systemic factors (Reason 1995). Identifying human errors by skill, rule, and knowledge-based errors supports the healthcare team in system approaches and strategies to improve safety (Bondurant et al. 2015). These categories can further assess what type of non-technical and technical skills leads to error (Sutton et al. 2013).

An adverse drug event (ADE) in healthcare can be a serious safety event leading to a fatal outcome. In many healthcare organizations, there is no gold standard to identifying ADEs. An important taxonomy on what an ADE is supports a common definition to provide the context of the type of error committed. When these events occur, it is important to have a multi-disciplinary team that can perform the root cause analysis on the ADE, implement processes to prevent it and develop audits to ensure they are being followed (Benning et al. 2011; Brilli et al. 2013; McClead et al. 2014). Additional teams can review the occurrence of adverse events in medical records and the evaluation of care as an additional layer of analysis of error (Phelan and Korst 2011).

Root cause analysis tools and task forces organized for high reliability have shown to directly impact in preventing and mitigating errors in healthcare (Durani et al.

2013; Hilliard et al. 2012; Ito et al. 2011; Larson et al. 2015; Sheridan-Leos 2014; Wright 2015). These task forces look at organizational processes that may contribute to human error to include work environment and malpractice concerns (Brennan et al. 2015; Singer et al. 2015). Many of the articles in the literature referred to utilizing Reason's Swiss Cheese model as the one of the best practices to learning about the human and system factors that contribute to active and latent failure (Durani et al. 2013; Hilliard et al. 2012; Ito et al. 2011; Larson et al. 2015; Sheridan-Leos 2014; Wright 2015).

An Ohio Children's health care system demonstrated one of the most prominent improvements in the literature when they organized for high reliability to decrease human and system error (Lyren et al. 2015). They trained 30,000 of their employees on key principles of HRO and created five task forces to support their journey towards high reliability: Error Prevention, Leadership Methods, Cause Analysis, Lessons Learned, and Safety Governance (Lyren et al. 2015). This alignment for high reliability resulted in a decrease of their serious safety events by 55 percent, equating to 70 fewer children per year experiencing the most severe type of harm, in addition to millions of dollars saved (Lyren et al. 2015).

When performing a root cause analysis, there is no gold standard in assessing adverse events in medical records. Institute for Healthcare Improvement (IHI) Global Trigger Tool has been shown as a reliable tool to detect, track, and estimate the occurrence of adverse events. This tool utilized by a number of hospitals in the U.S. determines the level of safety in their organizations, trends of adverse events, and evaluation of their systems impact of decreasing error over time (Najjar et al. 2013; Sharek et al. 2011). Another tool often used to support the principle reluctance to

simplify is the Hospital Survey on Patient Safety Culture (HSOPSC) developed by the

AHRQ. The HSOPSC is a survey used to assess the patient safety culture across 12

dimensions from teamwork to non-punitive responses to error. Initially, this survey is

administered as a baseline and administered again over time to analyze whether or not the

safety culture improves (Hershey 2015; Ito et al. 2011).

Many articles focused on the development of tools and processes to promote

reluctance to simplify interpretations. As noted above in preoccupation with failure, the

FMEA tool can be used to develop plans and actions to mitigate risk by placing in

processes that counter complacency during complex events (Dean et al. 2012). These

processes should provide situational awareness and constant flow of information that is

complete, accurate, and organized to support the team in anticipating and containing error

(Itri and Krishnaraj 2012; Robertson et al. 2014; Sheridan-Leos 2014). These concepts

and tools are often embedded within crew resource management training (Wheeler et al.

2013).

Finally, science of safety analytics is recently being incorporated to understand

etiology of errors in healthcare (Kurth et al. 2014). These analytics provided risk severity

indexes to tasks such as the expected frequency of unsafe behavior or the nature, severity

of the injury if uncorrected and how many people would be affected by error (Kurth et al.

2014). These analytics provide systems and individual views to consider many multiple

factors that lead to error. These robust process improvement tools support a mindset to

promote the culture where no one takes anything for granted and people are encouraged

to express different points of view (Weick et al. 1999).

Table 4.   Reluctance to Simplify

RELUCTANCE TO SIMPLIFY
• Address non-technical and technical skills that lead to error[22]
• Adverse Drug Event Huddles/Audits[1-2, 20]
• Assess Human Errors by Skill, Rule, Knowledge[34]
• Assess interruptions[21]
• Aviation black box approach to find why adverse events occur[3]
• Concepts of information transfer: completeness, accuracy, organization[17]
• Create systems that situational awareness by an entire team[7, 13]
• Crew resource management concepts[14]
• Institute for Healthcare Improvement Global Trigger Tool to estimate occurrence of adverse events[28, 33]
• Look at organization processes that may contribute to human error[11]
• Review malpractice concerns and work environment that impact medical error[9]
• Root cause analysis tools and create task forces to organize for high reliability[6, 13, 18-19, 24, 32]
• Safety Science analytics to understand etiology[23]
• Survey: Hospital Survey on Patient Safety Culture[5-6]
• Teams to review occurrence of AE in medical records and evaluation of care[8]
• Review malpractice concerns and work environment that impact medical error[9]
• Root cause analysis tools and create task forces to organize for high reliability[6, 13, 18-19, 24, 32]
• Utilize results from Failure Mode Effect Analysis to develop plans and actions to mitigate risk[10]
• Utilize Reason Swiss Cheese Model as a way to assess human and system error[6, 13, 18-19, 25, 27]

Source: Created by author.

Sensitivity to Operations

The articles addressed by the sensitivity to operations HRO principle provided context how important it is share information and divergent viewpoints so that staff individually and collectively develop a clear picture of the situation. This operational awareness on the individual and collective integrates mindful approaches to anticipate and contain errors (Weick et al. 1999).

Quality improvement (QI) capabilities are instrumental to drive safe practices (Kurth et al. 2014). When an organization has QI capabilities, it can create feedback mechanisms to assess in real time and over a duration the current and future status of their operations. These are supported by daily management systems, dashboards, and Andon systems (Larson et al. 2015). These systems have shown significant impacts on promoting and integrating information across multiple systems increasing situational awareness.

Briefs, huddles, and debriefs are tools that bring individual and collective mindful exchanges of information to maintain situational awareness within operations (Allen and Capo 2014; Bondurant et al. 2015; Bowermaster et al. 2015; Morrison and Rudolph 2011; Najjar et al. 2013; Patterson et al. 2013; Sanchez and Barach 2012; Wheeler et al. 2013). Briefs, huddles, and debriefs further promote transparency and levels of situation awareness outside an individual and team area of operations to identify any potential for error (Mueller 2014; Wright 2015). This is especially important within healthcare when there are handoffs of care. Substandard handoffs that resulted in medical harm to the patient have led frequently to litigation that could have been prevented through appropriate training and education (Phelan and Korst 2011). Communication tools such as SBAR (Situation, Background, Assessment, Recommendation) promote an organizational structured approach to handoffs by highlighting pertinent details that the healthcare provider and receiving unit should know about the patient (Bondurant et al. 2015; Hershey 2015; Ito et al. 2011; Morrison and Rudolph 2011; Najjar et al. 2013; Robertson et al. 2014).

Sensitivity to operations is often complicated by interruptions and distractions in the work area. Integrating individual and collective mindful approaches can provide a holistic approach on finding way to mitigate distractions in the work area (Sheridan-Leos, 2014). To promote the environment for individuals and units to be sensitive to their operations is no easy task. The literature revealed that appropriate policies, practice standards, guidelines, and evidence based practice parameters are key to developing an environment sensitive to latent errors (Itri and Krishnaraj 2012; Milne et al. 2013; Phelan and Korst 2011). These standards should incorporate items such as appropriate safe staffing and what procedures or drugs require two person independent checks (Hershey 2015; Sanchez and Barach 2012; Wheeler et al. 2013).

When an error does happen, the articles recommended utilizing a safety governance task force to perform a peer review to add fidelity to the root cause analysis process and promote increased sensitivity to operations (Lyren et al. 2015; Phelan and Korst 2011). The Preventable Harm Index can also add insight on retrospectively analyzing how much of that error could have been prevented (Brillii et al. 2013; McClead et al. 2014). Another layer is to set up ways to record events in the future to find failures (Bowermaster et al. 2015). Surveys such as Junior Doctors & Safety Attitudes Questionnaire and Patient Safety Climate (PSC) may provide additional insights on how frontline healthcare workers view how sensitive their unit and system is to identifying latent errors (Durani et al. 2013; Zaheer et al. 2015).

Finally, family engagement is often overlooked as a way to mitigate error and increase reliability (Hilliard et al. 2012). Healthcare is one of the few industries that have a coveted relationship with the patient and their families. The families are often the

recipient of multiple exchanges across the spectrum of healthcare operations. Often they are the first to identify that there are inconsistencies with the delivery of healthcare. Integrating and keeping the family engaged will add another solid layer to promoting sensitivity to operations by promoting situational awareness, understanding, and projection of the delivery of healthcare to their loved one (Hilliard et al. 2012).

Table 5.   Sensitivity to Operations

SENSITIVITY TO OPERATIONS
• Brief-Huddle-Post/ debrief[3-4, 12, 14, 15, 21, 33-34]
• Daily Management systems, dashboard, Andon systems[19]
• Family engagement[25]
• Communication tools for reporting or performing handovers: SBAR/SIGNOUT[5-6, 17, 21, 33, 34]
• Medical-Legal Concepts[8]
• Mitigate distractions/work area[13]
• Peer Review[8]
• Policies, practice standards, guidelines, evidence based practice parameters[7-8, 30]
• Preventable Harm Index[1-2]
• Quality Improvement capability to drive safe practice[23]
• Record events to find failures[3]
• Safe staffing[5]
• Safety governance task force[24]
• Survey: Junior Doctors & Safety Attitudes Questionnaire, Patient Safety Climate (PSC)[18, 26]
• Transparency[29]
• Two person independent checks[12, 14]
• Understanding levels of situation awareness[27]

Source: Created by author.

Commitment to Resilience

The articles within Commitment to Resilience described various ways to build "capacity to cope with unanticipated dangers after they have become manifest, learning

to bounce back" (Weick et al. 1999). One of the prominent features in building resilience within the literature review is promoting a culture of safety that can contain emerging crisis through formal and informal networks. A culture of safety consists of an environment where shared beliefs and practices exist in an organization to detect and learn from errors (Phelan et al. 2011). Four subcultures support the foundation for a culture of safety: reporting culture, just culture, flexible culture, and learning culture (Benning et al. 2011; Brennan et al. 2015; Chassin 2013; Kurth et al. 2014; Najjar et al. 2013; Phelan and Korst 2011; Sheridan-Leos 2014).

A reporting culture is where people freely report error, accidents and near misses. It is important that the culture of reporting of errors should have a nonpunitive response to errors by avoiding condescending and demeaning remarks (Chassin 2013; Hershey 2015; Ito et al. 2011; Itri and Krishnaraj 2012; Larson et al. 2015; Miguel et al. 2011). By openly blaming individuals without understanding the human and system factors have shown to undermine organizational safety and set the conditions for additional errors to happen (Chassin 2013; Hershey 2015; Ito et al. 2011; Itri and Krishnaraj 2012; Larson et al. 2015; Miguel et al. 2011). Second victim refers to pain and suffering healthcare workers experience after making a health care error (Hershey 2015). Healthcare workers often face additional damage and blame for making an error due to the hierarchal nature of the healthcare system (Hershey 2015). Understanding the second victim concept will support an open, compassionate response to error and promote patient and healthcare workers safety (Chassin 2013; Hershey; 2015, Ito et al. 2011; Itri and Krishnaraj 2012; Larson et al. 2015; Miguel et al. 2011).

A just culture supports a nonpunitive response to error and balances the human and systemic factors of when an error happens (Hershey 2015). This culture supports basing disciplinary action on the type of behavior rather than the outcome of error. There is a clear understanding of the line between blameless and blameworthy actions (Reason 1995). It is supported by rewarding the behavior of reporting errors and working in multidisciplinary teams to put in place processes to prevent future error (Allen and Capo 2014; Sheridan-Leos 2014).

Flexible culture consists of authority patterns that can be reconfigured when safety or other types of important information is exchanged, especially in times of crisis (Phelan et al. 2011). There are many complex and integrated components of the healthcare care system. In order to decrease error and increase reliability in the rapid pace of the delivery of healthcare, the healthcare team will need to maintain flexibility to anticipate and contain error (Phelan et al. 2011).

The final component in building a culture of safety is a learning culture. A learning culture is a collection of characteristics that embed professional development to learn and implement major reforms of when and how to anticipate and contain error (Phelan et al. 2011). This atmosphere ensures that knowledge is shared between teams, individuals and systems. There are many tools that promote a learning culture and it is often supported by education, training and simulated programs. Education, training, and workshops focused on quality improvement and safety analytics have been shown to decrease errors (Kurth et al. 2014). A feedback mechanism that supports these workshops is developing a lessons learned task force (Lyren et al. 2015). Emergency drill simulations and simulations to train resilience after conducting an error are additional

tools to increase resilience (Hilliard et al. 2012; Milne et al. 2013; Patterson et al. 2013; Wheeler et al. 2013). These simulations work to develop capabilities to recover from failure, contain its effects, and implement bounce back interventions that identify and mitigate error (Bondurant et al. 2015; Sanchez and Barach 2012). A safety coach program to train front line coaches to support peers on effective use of prevention error techniques decreased error across their healthcare system (Brillii et al. 2013). Learning organizations also look for ways to manage time, stress, and fatigue on individuals and teams (Morrison and Rudolph 2011; Sutton et al. 2013; Wright 2015). In addition, organizations that developed ways to decrease interruptions to decrease stress and workloads have directly decreased preventable error rates (Morrison and Rudolph 2011; Sutton et al. 2013; Wright 2015). This is turn alleviates stress and fatigue on the system that would otherwise promote error and possibly lead to catastrophic results. The establishment of these four subcomponents of a culture of safety set the conditions for an organization that is informed, safe, supportive, and highly reliable. The culture of safety supports commitment to resilience, by building people's competence and response repertories on how they quickly address errors, minimizes their effects, and continue operations (Weick et al. 1999).

Table 6.   Commitment to Resilience

COMMITMENT TO RESILIENCE
• *Bounce back* interventions that identify and mitigate error[34] • Blaming individuals will undermine organizational safety[5-6, 7, 16, 19, 32] • Develop ways to decrease interruptions to decrease stress and workload[21-22, 27] • Development of capabilities to recover from failure and contain its effects[12] • Education, training, and workshops focused on Quality Improvement and Safety analytics[23] • Emergency Drill simulations[30] • Lessons learned task force[24] • Look for ways to manage time, stress, and fatigue on teams[21-22, 27] • Nonpunitive response to error, avoid condescending, and demeaning remarks[5-7, 16, 19, 32] • Reward staff for working in multidisciplinary teams[4, 13] • Safety coach program to train front line coaches, peers on effective use of prevention error techniques[1] • Simulation to train resilience[14-15, 25] • Understanding of "2nd Victim" [5-6, 7, 16, 19, 32]

Source: Created by author.

Deference to Expertise

The articles addressed deference to expertise by providing tools to cultivate a culture in which team members and organizational leaders defer to the person or teams that have the most knowledge and expertise relevant to the issue at hand regardless of their hierarchical position (Bondurant et al. 2015; Mueller 2014; Sheridan-Leos 2014). A starting point is respecting and trusting frontline workers such as junior doctors and nurses to make decisions and avoid rigid hierarchies (Chassin 2013; Hershey 2015; Milne et al. 2013). As the Macro (Strategic), Meso (Operational) systems support and respect microsystems (tactical and unit levels) this will cultivate a culture to seek out those with the most relevance to the issue especially when it comes to identifying and mitigating the effects of an error (Bowermaster et al. 2015; Sheridan-Leos 2014). This has been one of

the distinct challenges in overcoming in healthcare primarily due to hierarchies and complexities within the healthcare system.

However, models of care based on interdependent, collaborative, interprofessional teamwork have shown significant promise in decreasing and mitigating errors (Itri and Krishnaraj 2012; Phelan and Korst 2011). Multidisciplinary microsystems teams utilized for investigating hospital acquired infections, and adverse drug events have shown some of the greatest impacts in decreasing error that resulted in serious harm (Allen and Capo 2014; Brillii et al. 2013; Larson et al. 2015; McClead et al. 2014; Miguel et al. 2011; Patterson et al. 2013, Phelan and Korst 2011; Sutton et al. 2013; Wheeler et al. 2013). Promoting a teamwork-multidisciplinary approach to decision making also fosters an environment that integrates situational awareness and understanding to anticipating and decreasing errors (Dean et al. 2012; Sanchez and Barach 2012). In one hospital system with 5,000 employees, they experienced a decrease of 93 percent of their serious harm rate when implementing these models (Lyren et al. 2015).

Team Strategies and Tools to Enhance Performance and Patient Safety (TeamSTEPPS) and Crew Resource Management (CRM) training offer an evidence based platform and expedient means to facilitate deferring to expertise understanding (Agency for Healthcare Research and Quality 2015). These are the most researched and implemented programs that have shown consistently through it tools focused on building: communication, situation monitoring, leadership, mutual support, and team structure, to decrease error (Ito et al. 2011; Itri and Krishnaraj 2012; Larson et al. 2015; Phelan and Korst 2011; Sutton et al. 2013; Wright 2015).

Deference to expertise is particularly crucial during times of trouble, high-paced operations, and when employees are faced with unexpected events. The key components in managing error and increasing reliability is an awareness that if something unexpected happens, people know who has the expertise to respond, and the people in the organization value expertise over the hierarchies (Weick et al. 1999).

Table 7.   Deference to Expertise

DEFERENCE TO EXPERTISE
• Allow frontline workers (junior doctors/nurses) to make decisions and avoid rigid hierarchies[5, 16, 30]
• Cultivate culture that team and leaders defer to person with the most knowledge relevant to the issue[13]
• Macro, Meso support and respect microsystems[3]
• Models of care based on interdependent, collaborative, interprofessional teamwork[7, 8]
• Multidisciplinary microsystems based team for Adverse Drug Event investigations[2, 4, 8, 14, 15, 19, 22, 32]
• Multidisciplinary microsystems based team for Hospital Acquired Infection investigations[1, 4, 8, 14, 15, 19, 22, 32]
• Seek out those with the most relevant and knowledge and expertise relevant to the issue[13, 29, 34]
• TeamSTEPPS/CRM training to facilitate deferring to expertise understanding[6-7, 8, 19, 22, 27]
• Teamwork-Multidisciplinary approach to decision making[10, 12]

Source: Created by author.

HRO Tools that can be used by the MHS to decrease preventable error

The literature review shared a wide array of HRO tools that are utilized in many healthcare organizations that have shown statistical significance in preventing medical error. Medical error is a valid concern in deployed environments as it is in U.S. The

austere environment and rapid transitioning nature of operations often leave members of the MHS team in the dark of what if any medical errors they did.

Recent published articles based off the data found in Joint Theatre Trauma Registry (JTTR) have proven that there are variances in the delivery of care and quality improvement processes across the MHS in deployed environments (Eastridge et al. 2009). This is likely due to the constraints, limitations, and risks of delivering healthcare on a battlefield that is constantly changing (De Lorenzo and Pfaff 2011). In addition, there seems to be further delineation of how the MHS delivers healthcare in immature and mature combat environments (Budinger 2008; Clark and Brewer 2008). However, initiatives such as clinical practice guidelines and CQM initiatives have improved survivability rates (Eastridge et al. 2009; Budinger 2008; Clark and Brewer 2008).

Virtually every tool screened in the literature review could be used in a deployed environment to decrease preventable error. The main themes in the articles were when healthcare entities organized their tools within high reliability concepts they saw a decrease in their preventable error rates. These HRO tools have been used for decades to improve quality of care and decrease error. The unique variances were in organization, development, implementation, and sustaining the practice of high reliability. These tools found in the literature review have been utilized and are in our MHS.

Since these tools are within our MHS, there are now questions that beckon to be answered. If these tools are within our MHS and we have used them in our deployed environments, why do we still experience preventable errors? Why do we still have patients experiencing harm caused by preventable errors? Why have patients died because of preventable errors? The MHS has utilized quality management programs such

as Clinical Quality Management (CQM) in a mature deployed environment to improve the quality of healthcare delivery (Budinger 2008; Clark and Brewer 2008). So why are there still preventable errors occurring in the MHS?

When quality improvement programs such as CQM fail, it is often because the cognitive infrastructure is underdeveloped (Weick et al. 1999). HROs principles provide the cognitive infrastructure that enables simultaneous adaptive, flexible learning and high reliable performance (Weick and Sutcliffe 2015). The cognitive infrastructure refers to how well an organization is set up for high reliability operations. It assesses how well the organizations cognitive infrastructure supports sensemaking, continuous organizing, and adaptive managing (Weick and Sutcliffe 2015).

Sensemaking is supported by the five HRO principles and focuses how well employees evaluate a situation while simultaneously act and partially determine the nature of the error. It is an attempt to grasp a developing situation like a preventable error in which the observer (healthcare providers) can affect the trajectory of that development (Weick and Sutcliffe 2015). Continuous organizing refers to the dynamic activity of high reliability organizing to describe ongoing, collective efforts to improve and maintain reliability. Finally, adaptive managing and to a certain degree leadership is the task of attending to, sorting out, and prioritizing competing demands (Weick and Sutcliffe 2015). Projection of adaptive managing is often facilitated when managers can provide their own view of the current situation in way that promotes collective sensemaking (Weick and Sutcliffe 2015).

This cognitive infrastructure further defines why HROs focus on failure and reliability instead of success and efficiency (Weick et al. 1999). A HRO mentality would

not focus on a 98 percent survivability rating that we have experienced in Iraq and Afghanistan wars (Joint Theatre Trauma System 2014). A HRO mentality would focus on the other 2 percent of casualties that did not survive. It would focus to see if there were any preventable errors and processes that contributed to the other 2 percent. A HRO mentality would state that 98 percent is not good enough. However, it is important to mention that HROs are not looking to have zero defects. Instead, the HRO mentality is a relentless pursuit to find ways to anticipate and contain preventable errors and increase reliability. Organizing for high reliability based on the five HRO principles provide the collective mindfulness that is the backbone of the cognitive infrastructure to decease preventable error and increase reliability (Weick et al. 1999).

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Strategies that could be applied in implementing
HRO tools in deployed operations

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The purpose of implementing HRO tools in deployed operations is to increase reliability of our MHS by decreasing preventable error and improving quality of care. In their 2004 white paper, *Improving the Reliability of Health Care*, the Institute of Healthcare Improvement (IHI) provides a process of applying principles of reliability to healthcare systems through a three-step model: (1) prevent failure (a breakdown in operations or functions), (2) identify and mitigate failure when it occurs and intercede before harm is caused, (3) redesign the process based on the critical failures identified (Nolan et al. 2004).

Reliability is a measurement of how consistently a system operates without failure over time. It is a measurement often used by industries such as aircraft carriers and their flight decks, nuclear submarines, nuclear plants, aviation to include airport security,

electric companies, railroad operations, firefighting, banking, and more recently in healthcare (Weick et al 2015).

Reliability is measured this way:

$$\text{Number of actions that achieves the intended result} \div \text{Total number of action taken} = \text{Reliability (Nolan et al. 2004)}$$

For example, a system that operates nine out of 10 times correctly is considered to have a reliability score of 10^{-1} or 90 percent reliable. A system that operates 99 out of 100 times correctly has a reliability score of 10^{-2} or 99 percent reliable. A system that operates 999 out of 1000 times has a reliability score of 10^{-3} or 99.9 percent reliable. Aviation passenger safety and Nuclear Plants have a reliability score of 10^{-6} or 99.9999 percent reliable (Weick et al. 2015). When it comes to preventable errors in healthcare, the majority of healthcare organizations across the globe have an average error rate of 10 percent which gives them a defect rate of 10^{-1} or only 90 percent reliable (Nolan et al. 2004).

Utilizing healthcare as an example, a 10^{-1} (90 percent) reliability means a process could fail to be effectively applied for one out of 10 patients (Nolan et al. 2004). For example, if 90 percent of patients on a ward (10 patient unit) received their antibiotic medication on time, the reliability of that process as measured by defect rate is 10^{-1} or only 90 percent reliable (Nolan et al. 2004). This means that there is at least one patient not receiving their antibiotics on time. This can lead to second and third order effects caused by the delay in receiving the antibiotic medication on time. The delay could cause the antibiotic ability to reach a therapeutic level to support the patient immune system in

fighting or destroying bacteria, which if not treated in time, could have dire consequences on the survivability of the patient.

The application levels of strategies to increase reliability are different primarily in their design characteristics on how they integrate their systems to improve reliability. Level One focuses on 10^{-1} prevention strategies. These strategies include a basic standardized approach to using equipment, standard guidelines, memory aids such as checklists, feedback mechanisms regarding compliance with standards, and awareness-raising and training. Once a standardized process is in place it is recommended to use the Failure Mode Effect Analysis (FMEA) tool to evaluate the structure of systems and predict performance (Nolan et al. 2004).

Level Two focuses on 10^{-2} identify and mitigate strategies. The strategy is intentionally designing processes with tools and concepts based on the principles of human factors engineering to error proof. These tools or systems seek to eliminate ambiguities and focus on catching or identifying instances when a standardized approach is not used. Error-proofing systems leverage reminders (checklists or alarms to prompt actions), differentiation (color coding alarms), constraints (system that catches two medications that are not compatible), and affordances (making the desired action the default) to design more reliable processes. It is supported by sustaining Level One strategies, and building decision aids, eliminating ambiguities, piggybacking protocol steps on established habits and patterns, and again performing FMEA to evaluate the structure of systems in place and predict their performance (Nolan et al. 2004).

Level Three focuses on 10^{-3} redesign strategies. It involves reevaluating the weaknesses in the design of Level One and Two strategies that are leading or might lead

to failure. This review evaluates structures and linkages across the healthcare spectrum to include for example different locations of care, transfer of information in handovers, and variances in following clinical practice guidelines. The FMEA tool is likely the most important tool to apply at this level to analyze and evaluate systems and their performance. It is supported by sustaining Levels One and Two, and adding processes to determine weaknesses or most frequent failure, automated solutions that minimize human factors that contribute to error, and FMEA (Nolan et al. 2004). The reliability strategies of prevent, identify-and-mitigate, and redesign approach provide a strategic systematic way of applying principles of reliability to healthcare to decrease preventable error.

Table 8.   Strategies for Designing Systems of Care to Increase Reliability

STRATEGIES FOR DESIGNING SYSTEMS OF CARE TO INCREASE RELIABILITY				
Reliability Strategy Level	Processes	Strategies	Reliability Rate	Examples of Reliability Levels in Healthcare
Level One Prevention	Creation and use of a standardized approach to care (common process), emphasis on training and reminders	Basic standardization, memory aids, feedback mechanisms, awareness-raising and training, utilize the Failure Mode Effect Analysis (FMEA) tool to evaluate the structure of systems and predict performance	10^{-1} (90%), 1 failures in 10 cases	Healthcare overall to include civilian and military health organizations, patient identification, communication in transitions of care
Level Two Identify and Mitigate	Processes intentionally designed with tools and concepts based on the principles of human factors engineering. Focus on "catching" or identifying instances when the standardized approach is not used	Sustain Level 1 strategy, and add: Error Proofing Systems, building decision aids, eliminate ambiguities, piggyback protocol steps on established habits and patterns, seek to reduce opportunities for humans to make mistakes, FMEA	10^{-2} (99%), 1 failure in 100 cases	Hand hygiene, medication administration, diagnostic errors
Level Three Redesign	Process measures indicates a well-designed system with attention to processes, structure, and relationship to outcomes	Sustain Level 1 and 2, and add: Processes to determine weaknesses or most frequent failure, automated solutions that minimize human factors that contribute to error, FMEA	10^{-3} (99.9%), 1 failures in 1000 cases	Right care (clinical effectiveness), preventable errors or adverse events (i.e., wrong site surgery)

Source: Created by author. Adapted from Thomas Nolan et al., "Improving the Reliability of Healthcare," *IHI Innovation Series White Paper* (Boston, MA: Institute for Healthcare Improvement, 2004).

<u>Tracking and Measuring Preventable Errors</u>
<u>in Deployed Environments</u>

Throughout the literature review, many articles offered various ways to track and measure preventable error. The HRO tools utilized focused on robust process improvement (RPI) tools to track, measure, and decrease preventable error. The concepts used to track these measurements could be applied in deployed environments taking into consideration the challenges of working within an austere combat zone. From the literature review, it would seem that there is no data on how often preventable errors happen across the roles of medical care in deployed environments. We do get an understanding from the literature review that the MHS is concerned and diligently working on processes to decrease preventable errors that have happened in deployed environments.

Recently the Defense Health Board (DHB) released a review titled, *Combat Trauma Lessons Learned from Military Operations of 2001-2013* (Defense Health Board 2015). In the review, the performance improvement chapter recommended ongoing analysis of combat injuries to identify potentially preventable adverse events (Defense Health Board 2015). These recommendations understood the significant impact RPI programs had in saving lives on the battlefield by decreasing preventable error through improving clinical practice guidelines (CPG), staffing capabilities, evacuation techniques, infrastructure, communication, and equipment (Defense Health Board 2015). An example of the impact of a RPI is a measurement of mortality when comparing pre and post implementation of a CPG burn resuscitation protocol. Prior to implementation of the CPG, burn patients had a 36 percent mortality rate. Post CPG implementation, burn patients had a mortality rate of 18 percent (50 percent decrease in mortality) after a 94

percent compliance rate of following it (Eastridge et al. 2009). This significant statistic showed that following a CPG could result in saving additional lives in casualties injured from a burn. A 94 percent compliance rate is good but still only yields 10^{-1} reliability rate.

In order to increase the reliability rate and measure it, significant processes would need to be implemented. The IHI model as previously discussed provides a process of applying principles of reliability to healthcare systems to track and measure preventable errors. There are many examples of how the IHI model of increasing reliability could be applied across combat casualty care. Because of the plethora of the many processes that could be measured and tracked in combat casualty care, this author chose to use handover of care as an example to show how the implementation of the IHI model could be used to increase reliability across the roles of medical care.

As stated previously during a hospitalization a patient will experience up to 24 handovers of care and be subjected to an estimated 13 percent error rate associated with additional risks from the handover (Robertson et al. 2014). Handovers of care happen very quickly across and within each of the roles of medical care from evacuating a casualty from point of injury (Role 1) to a Forward Surgical Team (Role 2) to a Combat Support Hospital (Role 3) and back to a hospital in the US for definitive care (Role 4). It is reasonable to assume there is a significant amount of handovers that happen in a deployed environment and that a 13 percent error rate could be applied as a baseline to give context of how often errors happen in handovers.

The first step in the IHI model of increasing reliability is to create a standardized approach for handover of care in a deployed environment (Nolan et al. 2004). Based on

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the literature review, the handover should provide a standardized format for information

transfer and a taxonomy for handovers. Handovers require a template that covers settings,

personnel, means of information transfer, standardization of procedure, feedback,

summarization, task allocation, and recording of the event (Robertson et al. 2014). Just

like there is a taxonomy for roles of medical care, there should be a taxonomy for

handovers. This could possibly be seated within the roles of medical care and within

inpatient and outpatient settings. The importance of applying a taxonomy to handovers

will provide a common language to measure so that RPI programs can accurately

measure and focus efforts on improving the outcomes of handovers through feedback

mechanisms (Robertson et al. 2014).

The second step is to evaluate adherence to the standardized approach (Nolan et

al. 2004). This consists of performing an audit for example by pulling a random sample

of ten medical charts to screen to see if documentation correlates with the standard

approach for handover. This audit can evaluate various data fields of the standardized

process for handover but should focus primarily on three aspects of information transfer:

completeness, accuracy, and organization (Robertson et al. 2014). A question that could

be asked during the audit is finding what percentage of casualties followed the

standardized approach to handover. If it is around 90 percent accurate, then the current

reliability of our processes is 10^{-1}. If it were less than 90 percent, we would need to look

at Level One strategies of the IHI model to increase reliability before we moved to the

next step (Nolan et al. 2004).

The third step is to move from Level One toward Level Two performance (Nolan

et al. 2004). This movement from 10^{-1} to 10^{-2} reliability requires Level Two strategies

that consist of eliminating redundancy, building decision aids, and error proofing

systems. Application of technologies could be applied to build decision aids to remind

healthcare providers (HCP) on what information should be transferred to ensure

continuity of care and avoidance of preventable error. If adherence to the standardized

process is greater than 90 percent, we are ready to move to the next step.

The fourth step is move to Level Two, which consists of continual monitoring of

critical processes and working on mistake proofing (Nolan et al. 2004). Since a

standardized process is in place, this step further expands on creating strategies to

identifying failure while using the process. In context of handovers, what strategies

should we use to continually identify failure in handovers in inpatient, outpatient, and

evacuation of patient settings? This expanded view creates additional data points that

could be measured to identify near misses, preventable errors, and provide feedback on

barriers to adhering to the standardized process of doing handovers. In addition, continual

utilization of the common methods of error proofing systems with reminders, constraints,

differentiation, and affordance work to further enhance reliability of handovers. These

initiatives would begin to yield a 10^{-2} reliability.

The fifth and final step is move toward Level Three, which promotes reflection

and understanding of the failure modes within a standardized process feedback where

individual elements are not carried out (Nolan et al. 2004). These processes should be

tested to determine its weaknesses and more frequent failure modes. Based on the

feedback, standards should be remodeled to achieve the best results. This may include

system wide or specific structural change concepts. The FMEA tool would be ideal to

utilize in looking at how well the standards of handovers are being done across the roles

of medical care and see if there are any individual or system elements that continue to decrease reliability. If there continues to be failure within the system, then the standardized process to do handovers should be remodeled, retested to achieve the best results in promoting high quality health care and decreasing preventable error. This final step of implementation to track and measure data points across the system provides ongoing feedback mechanisms that identify, contain, and mitigate preventable errors and yields a 10^{-3} reliability.

<div align="center">

Existing challenges and opportunities
in implementing HRO tools

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It would seem that every HRO tool in the literature review has been applied within the MHS at various roles of medical care across the battlefield. The challenge has been in maintaining standards and applying them in a systematic way to decrease preventable error. This is evident in how patients were transferred across the roles of medical care and in application of clinical practice guidelines (Eastridge et al. 2009).

Every service has various ways in how they train, develop, implement their changes, and gathers data for analysis. Members of the same interprofessional team may use different terminology depending on which sister service they are from. Every service has various medical capabilities for each role of medical care to support their services needs as evident by Figure 6 below (Wyslling, Philip 2015). However, despite the medical capabilities within each of the services, it is highly unlikely that each service would be able to provide the full spectrum of combat casualty care in a deployed environment. Each of the services are interdependent on one another to deliver combat casualty care from Role 1 to Role 4, regardless of their internal capabilities.

Figure 6. US Military Roles of Medical Care

Source: Philip Wyslling, "US Military Roles of Medical Care" (Presentation at the CGSC Fort Leavenworth, KS, August 5, 2015).

The complexity of the MHS in a deployed environment offers additional challenges in organizing for high reliabiity. These challenges can come in allocation of resources in personnel, monies available, capabilities, and can be mission dependent. This is particularly true when seeking how to standardize and what type of standards of care should be implemented in deployed environments. A standard of care is especially

challenging to maintain in immature theatres. For example, the sickest patient in a hospital back in the US will likely be afforded the full spectrum of healthcare capabilities but in a deployed situation that same patient may be deemed expectant because of the limited resources and capabilities available and the operational tempo (Cohen 2004).

Many MHS experts do agree from lessons learned that there should be some type of combat standard of care to increase reliability. However the MHS standards of care should be refined to meet the often unique and variable circumstances when delivering combat casualty care (Cohen 2005; Budinger 2008; DeLorenzo and Pfaff 2011). This is where the opportunity to apply HRO tools would be most beneficial in supporting the MHS initiatives in the delivery of combat casualty care while minimizing preventable error. Application of HRO tools will work to ensure that the casualties we are entrusted to care for are not experiencing further injury from our preventable error.

The IHI model of improving reliability in healthcare provides an opportunity to apply its concepts to integrate processes for actions over time that is suitable, feasible, and acceptable (Nolan et al. 2004). The IHI model can further outline HRO tools application into short, medium, and long term strategic priorities for error prevention, identify and mitigating error, and redesign concepts to further decrease preventable error and increase reliability over time (Nolan et al. 2004).

The first priority would be to focus efforts on prevention. These actions should focus on assessment of our current MHS delivery of combat casualty care and work on incorporating HRO principles and tools to decrease preventable error. Short-term goals would consist of a rapid assessment of the MHS reliability in combat casualty care utilizing the IHI Global Trigger Tool (GTT) to get an estimate of preventable errors.

Although, the MHS has a 98 percent survivability rating, we do not know how often preventable errors occur. The IHI GTT tool is a reliable tool to detect, track, and estimate the occurrence of preventable error (Najjar et al. 2013; Sharek et al. 2011). In addition, the IHI tool can be used to evaluate which capabilities should be organized for high reliability. The Joint Trauma System and the Joint Theater Trauma Registry have provided many examples of aligning medical capabilities to increase reliability of combat casualty care through best practices and CPGs (Eastridge et al. 2009). Medium-term goals should incorporate a standardized approach for combat casualty care to decrease preventable error. These HRO tools should provide basic standardization, memory aids (checklists, graphics), feedback mechanisms, and raising awareness and training on HRO principles (Nolan et al. 2004). Long-term goals should be embedding HRO principles in training and doctrine, and further organizing for high reliability to create the cognitive infrastructure to anticipate and contain preventable error. Organizing for high reliability would normally be the first step but given the unique culture of each of the services and the challenges to incorporate rapid change, this remains a long-term goal.

The second priority would be to focus on identifying and mitigating errors. Strategic priorities would focus on identifying instances when standardized approaches are not used (Nolan et al. 2004). Short-term goals would be to further focus on training on how human and system factors can identify preventable error when a standardized process is not used. In addition, incorporate HRO tools that identify and can mitigate preventable error. This leads to medium-term goals that will work to eliminate ambiguities in the way tasks are performed. These ambiguities often occur depending on if it is an immature or mature theater and resources available. Quality management

models such as the Clinical Quality Management (CQM) often create ambiguities in a deployed environment (Cohen 2005). CQM can also create a layer of bureaucracy where the paperwork required for each casualty actually outnumbers the amount of casualties seen in theatre (DeLorenzo and Pfaff 2011). This type of bureaucracy may create an environment where healthcare providers create workaround solutions and do not adhere to standards because of the austere environment they maybe in. Caution should be exercised when implementing any quality management model with ambiguities in order to prevent decreasing the effectiveness of the MHS ability to deliver combat casualty care. Long-term goals would focus on incorporating the four common methods of error proofing techniques (reminders, differentiation, constraints, and affordances) into maintaining adherence of a standardized process. Many of the HRO tools that provide error prevention techniques in the literature review can be used to further support adherence to standards of care.

The third priority would be to focus on redesigning. HRO robust process improvement (RPI) tools will play an important role in redesigning the MHS to increase reliability. Since there is a considerable amount of data available from the JTTR, the analysis from the IHI GTT can provide short, medium, and long term goals in addressing weaknesses in the design, processess, and structures used to decrease preventable error (Nolan et al. 2004). Short-term goals would analyze data from Joint Theatre Trauma Registry utilizing IHI Global Trigger Tool to see where there are still weaknesses in the design, processes, and structures utilized to decrease preventable error. Medium-term goals focus on implementing automated solutions that minimize human factors that contribute to error. An example of this would be the Burn Resuscitation Decision Support

System (BRDSS). This is an medical device designed to guide healthcare providers on how to administer and optimize fluid resuscitation in severly burned patients (Salinas et al. 2011). The design of the BRDSS incorporated the four common methods of error proofing and human factors that lead to preventable error. The addition of the BRDSS improved the fluid management of severely burn patients to include decreasing the amount of fluid volume required during resuscitation (Salinas et al. 2011). Long-term goals should focus on utilizing the Failure Mode and Effect Analysis (FMEA) tools to constantly reassess the reliability and performance of structures. Additionally, the FMEA could be used to also predict the reliability of the MHS in various future deployed environments in decreasing preventable error.

Table 9. Integrations for Actions Over Time

Priority	INTEGRATION FOR ACTIONS OVER TIME		
	SHORT	*MEDIUM*	*LONG*
Prevention *(Level 1, 10^{-1})*	Utilize IHI Global Trigger Tool to get an estimate of preventable errors. In addition, see which capabilities can be organized for high reliability	Utilize concepts from HRO tools to create basic standardization, memory aids, feedback mechanisms, awareness-raising and training on HRO principles	Embed HRO principles in training and doctrine to create the cognitive infrastructure to continue to anticipate and contain preventable error
Identify and Mitigate *(Level 2, 10^{-2})*	Training on human and system factors and utilize HRO tools to identify and minimize the effects of preventable error	Eliminate ambiguities in the way tasks are perform across the MHS in combat casualty care	Incorporate error proofing techniques into maintain adherence to a standardized process
Redesign *(Level 3, 10^{-3})*	Analyze the data from Joint Theatre Trauma Registry utilizing IHI Global Trigger Tool to see where there are still weaknesses in the design, processes, and structures	Implement automated solutions that minimize human factors that contribute to error	Utilize the Failure Mode and Effect Analysis tools to constantly reassess current and future reliability and performance of structures

Source: Created by author.

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The MHS has many combat casualty care structures and systems that are at various levels of reliability (Cohen 2005; Budinger 2008; DeLorenzo and Pfaff 2011). Applying the IHI model provides a systematic framework to prioritize and create short, medium, and long-term goals to integrate actions over time to increase reliability of the MHS and decrease preventable error.

Summary

When healthcare organizations arrayed their tools within HRO principles and concepts, they observed statistical differences in decreasing preventable error. These statistical differences resulted in a significant amount of lives saved, decrease in preventable error, decrease in the lives harmed by preventable error, and a substantial decrease in costs. The actual organization of the HRO tools created the conditions for institutions to decrease preventable error and increase their healthcare delivery reliability.

Challenges will remain to decrease preventable error in deployed environments. However, these tools offer a way to organize for high reliability by establishing the cognitive infrastructure to promote a collective mindfulness approach to decrease preventable error. These tools may offer the best chance to decrease preventable error when significant strain is placed on the MHS delivery of combat casualty care in deployed environments.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

It may be part of human nature to err, but it is also part of human nature to create
solutions, find better alternatives and meet the challenges ahead.
― Institute of Medicine, *To Err is Human: Building a Safer Health System*

Introduction

When the Institute of Medicine (IOM) released their *To Err is Human* report it

was a clarion call to the healthcare industry that it was contributing to a significant

amount of preventable deaths (Kohn et al. 1999). This report created a cascade of events

with fervor behind it to increase reliability and decrease preventable errors. However, an

additional report from the Institute of Healthcare Improvement (IHI) estimated that there

are 40 to 50 incidents of patient harm per 100 admissions that occur annually (McCannon

et al. 2007). This report clearly identified there was still the need for improvement. An

article in *Health Affairs* identified more than 1.5 million preventable errors occur

annually in the U.S. healthcare system (Bos et al. 2011). Yet despite multiple initiatives

and process improvements, a report released in 2013 stated an even higher statistic of

440,000 deaths annually is caused by preventable harm (James 2013). These multiple

reports created the body of evidence that healthcare is not as safe as it should be. In

addition, these reports highlight there is still more work and research to be done to

increase reliability of the healthcare systems and decrease preventable error.

The application of the principles of high reliability organization (HRO) offers the

most optimal approach to decreasing preventable error in healthcare (Chassin and Loeb

2013). HROs consistently conduct high quality and reliable operations, free of error over

a sustained period of time (Weick and Sutcliffe 1999). The five principles are: preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and deference to expertise created the cognitive infrastructure within HROs to anticipate and contain errors (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

In addition, frameworks such as the IHI model to increase reliability have been able to apply HRO tools to healthcare and improve reliability successfully over time (Nolan et al. 2004). These HRO concepts and tools are now beginning to integrate within the daily operations of the Military Health System (MHS) to decrease preventable error and increase reliability (U.S. Department of Defense 2014).

The main purpose of this research is to contribute to the growing body of knowledge of high reliability organization (HRO) tools in healthcare specifically their application to decrease and measure preventable error in deployed environments. Instituting the applications of HRO tools in deployed environments to decrease preventable error is a considerable challenge. This author acknowledges the amount of effort it takes to institute change in the MHS and understands that these changes will not happen overnight. However, utilizing the Doctrine, Organizational, Training, Material, Leadership and Education, Personnel and Facilities (DOTMLPF) to include policy considerations will offer a process to further analyze HRO tools and their applicability to the deployed environment. The analysis in chapter 4 provided the framework to make recommendations that are suitable, feasible, and acceptable to apply to the MHS in deployed environments.

<center>Doctrine</center>

Currently in joint doctrine focused on Health Service Support there is no mention on how to plan or prevent for medical errors on the battlefield. Key terms such as preventable error, adverse events, and reliability are missing from doctrinal terms (U.S. Department of Defense 2012). Although there are several lessons learned reviews that mention identifying potentially preventable errors and creating processes to decrease them. The how to plan to identify and mitigate preventable errors has yet to be included into joint doctrine (Defense Health Board 2015).

This significant gap in doctrine should be addressed across all the services within the MHS in joint doctrine. A standardized process should be included in doctrine on how to prevent, identify, mitigate, and redesign to decrease preventable errors. Terminology utilized in Institute of Healthcare Improvement (IHI) model to increase reliability offers the key language for healthcare providers to understand across the Services (Nolan et al. 2004). Terminology should additionally incorporate overall concepts from HRO principles to further support creating the cognitive infrastructure to decrease preventable error and increase reliability (Weick and Sutcliffe 2001; Weick and Sutcliffe 2007; Weick and Sutcliffe 2015).

Additional considerations for doctrine require a definition for a standard of care in deployed environments. This standard of care should be refined to meet the often unique and variable circumstances that the MHS finds itself when delivering combat casualty care (Cohen 2005; Budinger 2008; DeLorenzo and Pfaff 2011). Applying a standard of care should incorporate identifying the best clinical practice guidelines or HRO tools that have proven to decrease preventable error in deployed environments. The creation of a

standard and applying it creates the data points needed to implement robust process improvement tools to analyze adherence to it and make adjustments as necessary to improve outcomes.

Another doctrinal change should focus health support planning considerations. Out of the 14 health support planning considerations, not one of the planning consideration focuses on decreasing preventable error and increasing reliability (U.S. Department of Defense 2012). It is often an implied task that it will be done. However, this oversight in planning and organizing for high reliability may jeopardize patient safety.

<u>Organizational</u>

Organizing for high reliability would focus on how well the MHS is aligned to create an environment that supports sensemaking, continuous organizing, and adaptive managing (Weick and Sutcliffe 2015). The analysis revealed that the majority of the HRO tools mentioned in the literature review are currently in our MHS. The differences were how healthcare entities organized their tools within high reliability concepts to decrease preventable error.

The challenges to reorganize begin with identifying a lead agency for high reliability in combat casualty care. Currently, there is no lead or unifying agency to organize for high reliability in combat casualty care across the MHS. Lessons learned revealed that across the Services there was not optimal coordination, joint training, or consistent practices across the MHS when delivering combat casualty care (Defense Health Board 2015).

Since there is no lead or unifying agent, the first step in organizing for high reliability would be identifying one. The Joint Trauma System (JTS) would be ideal in becoming the lead agent since it currently handles the bulk of the work of combat casualty care from prevention to rehabilitation (Defense Health Board 2015).

Within the JTS, task forces could be created to organize for high reliability to decrease preventable error. These task forces primary responsibility is to evaluate organizational processes that may contribute to human error to include internal and external factors that contribute to increasing errors in the work environment (Brennan et al. 2015; Singer et al. 2015). There are five task forces recommended from the literature review. The Error Prevention Task Force focuses on training basic error prevention behaviors, which include: communication techniques, team member checking and coaching, and the use of tools that enhance sensemaking to decrease preventable error (Lyren et al. 2015). The Leadership Methods Task Force trained hospital leaders across strategic, operational, and tactical unit in specific methods to continuously reinforce basic error prevention behaviors and promote a just culture (Lyren et al. 2015). The Cause Analysis Task Force organized robust process improvements to root cause analysis on events such as near misses, and preventable error in order to provide the data to allocate resources appropriately (Lyren et al. 2015). The Lessons Learned Task Force facilitated the sharing of safety events across all services across internal and external healthcare systems to promote awareness of what worked and did not work in decreasing preventable error (Lyren et al. 2015). The Safety Governance Task Force is directed towards executive leadership, employees and partners in healthcare to promote leadership and collaboration and enhance their ability to support decreasing preventable error and

increasing reliability (Lyren et al. 2015). The research has shown that task forces have

directly impacted an organization's ability in preventing and mitigating errors in

healthcare (Durani et al. 2013; Hilliard et al. 2012; Ito et al. 2011; Larson et al. 2015;

Lyren et al. 2015; Sheridan-Leos 2014; Wright 2015).

<div align="center">Training</div>

Crew resource management (CRM) training has been the premier program

identified by the aviation industry that directly impacted decreasing their preventable

error and increased their reliability (Roberts 2003). CRM ensures that crews are trained

with proficiency to ensure everyone has a voice in identifying problems and what can be

done to solve them (Killen 2014). CRM is focused on crew communication, decision-

making, removing the hierarchal elements that come with decision making and ensure

those with knowledge of the problem have a voice in fixing it (Roberts 2003).

The official healthcare version of CRM is named Team Strategies and Tools to

Enhance Performance and Patient Safety (TeamSTEPPS). TeamSTEPPS is also focused

on building: communication, situation monitoring, leadership, mutual support, and team

structure (Agency for Healthcare Research and Quality 2015). TeamSTEPPS is part of

the MHS enabling frameworks to support HRO initiatives (Army Medical Department

2015). TeamSTEPPS should continue to be a mandated training program to support the

cognitive infrastructure for organizing for high reliability.

An additional training platform that supports teams to become high performing in

decrease preventable error is simulation training. Another layer of simulation is "in situ"

simulation. This particular type of simulation is a team-based training technique that

occurs on an actual patient care unit, utilizing the actual members of the healthcare team

to include their equipment and resources (Morrison et al. 2011; Wheeler et al. 2013).

Creating in situ simulations in a garrison environment can be challenging. These

challenges are compounded when working to create simulations that are of a deployed

joint environment in training centers and garrison environments.

However, there is opportunity to create simulations of deployed environments in

garrison across the Services. This is in part to realignments and combination of healthcare

organizations across the Services working in joint garrison locations across the globe.

The current reorganization could possibly support creating exercises that simulate

moving a casualty across the Services in a deployed environment in a central location.

These simulations should also include events that help the team build resilience in order

to develop capabilities to recover from failure, contain its effects and implement bounce

back interventions that identify and mitigate error (Bondurant et al. 2015; Sanchez and

Barach 2012). Joint training in simulation may not reveal or identify all the possible

latent failure or latent conditions that may lead to error. However, it will create the

cognitive infrastructure to increase the collective mindfulness to anticipate and contain

preventable error from harming casualties in a deployed environment (Morrison et al.

2011; Wheeler et al. 2013).

Finally, across the MHS, personnel should be trained on HRO concepts, human

and system factors that lead to preventable error. This training should include ways to

increase patient safety and risk management. This will further promote a culture of safety

and create the cognitive infrastructure to increase reliability and decrease preventable

error (Lyren et al. 2015).

Materiel

When an organization has quality improvement (QI) capabilities, it can create feedback mechanisms leveraging technology to assess in real time and over a duration the current and future status of their operations (Kurth et al. 2014). These are supported by daily management systems, dashboards, and Andon systems (Larson et al. 2015).

Incorporating science of safety analytics is also instrumental in understanding the etiology of error. These analytics provides risk severity indexes to tasks such as the expected frequency of unsafe behavior or the nature, severity of the injury if uncorrected and how many people would be affected by error (Kurth et al. 2014). These analytics provide a systems and individual view to consider many multiple factors that lead to error. These robust process improvement tools support a the mindset to promote the culture where no one takes anything for granted and people are encouraged to express different points of view (Weick et al. 1999).

Computerized software, medical devices and dashboards that show severity indexes have been key to decreasing preventable error (Kurth et al. 2014). Medical devices that incorporate error proofing systems with reminders, differentiation, constraints and affordances increase reliability and minimize human factors that create error (Nolan et al. 2004). As mentioned earlier an example of this would be the Burn Resuscitation Decision Support System (BRDSS). This is a medical device designed to guide healthcare providers on how to administer and optimize fluid resuscitation in severly burn patients (Salinas et al. 2011). The design of this medical device incorporates the four common methods of error proofing in addition takes into consideration the human factors that will lead to preventable error (Salinas et al. 2011).

Currently the MHS has varying degrees of these systems in deployed environments. However, there are great variances of these systems across the Services (Defense Health Board 2015). These variances in patient movement items can create the conditions for latent failure that can turn into active failure across the roles of medical care during evacuation. Standardization of these systems have shown significant impacts on promoting and integrating information across multiple systems increasing situational awareness and instrumental to drive safe practice.

<u>Leadership and Education</u>

Leadership engagement and education will be key in embedding high reliability principles, concepts, and practices into the Services. As addressed above a Leadership Methods task force should be created to train hospital leaders across strategic, operational, and tactical units across the roles of medical care. These leaders should be educated in specific methods to continuously reinforce basic error prevention behaviors and promote a just culture (Lyren et al. 2015). Key tasks for leaders is to engage in structured safety rounds, implement routine safety huddles, participate in daily safety rounds, and effectively influence staff to create a culture of safety.

 Leaders should understand how to create the cognitive infrastructure to decrease preventable error and increase reliability. The three concepts of sensemaking, continuous organizing and adaptive managing are the components to organizing for high reliability (Weick and Sutcliffe 2015). Leaders should learn how to create an adaptive management style to create the environment of collective sensemaking when unexpected events occur and figuring out what tasks a team should attend to, how to sort it out, and prioritize competing demands (Weick and Sutcliffe 2015).

Leaders will need to become educated on how to build resilience within the systems they are responsible for. Creating a culture of safety remains the best practice that leaders can promote to contain emerging crisis through formal and informal networks. A culture of safety consists of an environment where shared beliefs and practices exist in an organization to detect and learn from errors (Phelan et al. 2011). Four subcultures support the foundation for a culture of safety: reporting culture, just culture, flexible culture, and learning culture (Benning et al. 2011; Brennan et al. 2015; Chassin 2013; Kurth et al. 2014; Najjar et al. 2013; Phelan and Korst 2011; Sheridan-Leos 2014).

Another principle that should be addressed in leadership is the education and tools to promote a deference to expertise environment. These tools help to cultivate a culture in which team members and organizational leaders defer to the person or teams that have the most knowledge and expertise relevant to the issue at hand regardless of their hierarchical position (Bondurant et al. 2015; Mueller 2014; Sheridan-Leos 2014). Leaders at all levels of the MHS must support and respect microsystems (unit and tactical levels). This cultivates a culture to seek out those with the most relevance that can directly identify and mitigate the effects of an error (Bowermaster et al. 2015; Sheridan-Leos 2014). This has been the most challenging issue in overcoming in the MHS primarily due to hierarchies and complexities within the healthcare system.

Leaders should be educated on how to promote a teamwork-multidisciplinary approach to decision making. Leaders making an uninformed decision can create the conditions for failure within a system. Leaders must foster an environment that integrates

a culture of safety that increases situational awareness and understanding to anticipate and decrease errors (Dean et al. 2012; Sanchez and Barach 2012).

<u>Personnel and Facilities</u>

Within each of the Services, resources should be allocated to create a patient safety cell or risk management cell in a deployed environment. This is often common practice in garrison hospitals but often become an additional duty in deployed environments. This should not become an additional duty as doing so will directly decrease the effectiveness of this cell and increase the probability for preventable error to occur. Research has shown that organizing for high reliability, a patient safety or risk management cell is crucial in reducing preventable error, preventable harm, hospital mortality, and associated costs (Brilli et al. 2013).

This requirement may need to increase the current Table of Organization and Equipment (TO&E) of certain medical forces to accommodate having additional personnel trained in patient safety and risk management. This small increase has shown to pay dividends in many lives saved from preventable error, harm and deaths caused by it, and increased cost savings (Brilli et al. 2013).

The only consideration for facilities is analyzing them to see if they are structured and organized for high reliability. Do our current facilities contribute to the human and system factors associated with increasing preventable error or decreases it? Do our deployed systems promote safe patient flow throughout the roles of medical care? These questions could be analyzed and answered by the Failure Mode and Effect Analysis (FMEA) tool. The FMEA allows healthcare professionals to do a prospective risk assessment to see what complex process or technology might fail once implemented, the

impacts of that failure and identify ways to mitigate the risk (Dean et al. 2012; Hillard et al. 2012; Lyren et al. 2015).

Policy

The literature revealed that appropriate policies, practice standards, guidelines, and evidence based practice parameters are key to developing an environment sensitive to latent errors (Itri and Krishnaraj 2012; Milne et al. 2013; Phelan and Korst 2011). Degradation of capabilities is apparent as units bring their own policies and procedures to the fight. Policies and procedures should be tailored and standardized for deployable medical units across the MHS (Clark and Brewer 2008).

A macro look of the MHS provides us significant opportunities to gather data points and perform RPI in a systematic way. Fortunately, we have the data points available with tasks such as performing handovers in a deployed environment. There are about 128,267 records on file at the Joint Theatre Trauma Registry. Auditing these records with the Institute for Healthcare Improvement (IHI) Global Trigger Tool (GTT) to detect, track, and estimate occurrence of adverse events could provide us the level of safety of the MHS in deployed environments. Based on the IHI GTT analysis of trends of adverse events, policies, practice standards, guidelines, and evidence based practice parameters can be created to decrease preventable error and increase reliability of the MHS incrementally over time.

Summary

Recently within the MHS we have accomplished a 98 percent chance of survivability in deployed settings if a patient reaches a combat hospital alive (Joint

Theatre Trauma System 2014). This survivability rating is truly a significant accomplishment and the highest in our history as a MHS (Defense Health Board 2015). However, what about the other 2 percent that arrived at the combat hospital, could they have been saved? Of the 98 percent that arrived at our combat hospitals how many suffered an additional injury from our care and living with those effects today?

Although we look at this as a small percentage, how many of them entrusted us with their care and how many of us violated that trust by committing a preventable error that led to harm? Behind the percentages, there is a wife, a husband, a mother, a father, a sister, a brother, America's daughters and sons that could possibly be alive today participating in the great joys of life.

Of course, none of this is intentional. People do not join the healthcare field to commit harm, they do so to answer the clarion call to relieve suffering and impart hope. Many healthcare providers experience personal trauma from committing preventable error that they carry the rest of their lives. However, our current reliability in healthcare is considered highly unsafe and has led to many lives lost and harmed due to preventable errors committed by healthcare providers. If our reliability sole data point is survivability then we are not where we should be. This is a problem not just for the MHS but a global issue in healthcare.

However, the HRO concepts and tools provide a way forward through this complex situation. This is where the HRO mentality emerges and begins to shift the paradigm in understanding reliability in healthcare and making it safer. The HRO mentality regards close calls and near misses as a kind of failure that reveals potential dangers rather than as evidence of our success and ability to avoid danger (Weick and

Sutcliffe 1999). The HRO mentality would consider that 98 percent is not good enough and 2 percent is too high. The HRO journey is a relentless pursuit to increase reliability. This paradigm shift must occur in the MHS and throughout healthcare organizations. This profound shift will be the difference in decreasing preventable error in combat casualty care. This shift will help us keep our coveted promise to America's daughters and sons to bring them home safely and conserve the fighting strength.

APPENDIX A

EVIDENCE TABLES FROM ARTICLES INCLUDED IN LITERATURE REVIEW

#	Type of Evidence/ Study	Strength of Evidence	Quality of Evidence	Title	Year	Author	Journal	Sample Size / Adequate?
1	NR	Level VI	A = High	A comprehensive patient safety program can significantly reduce preventable harm, associated costs, and hospital mortality	2013	Brilli RJ, et.al.	J Pediatric	1 hospital
2	NR	Level VI	A = High	An internal quality improvement collaborative significantly reduces hospital-wide medication error related adverse drug events.	2014	McClead RE Jr, et.al.	J Pediatric	1 hospital
3	R	Level VI	A = High	Application of the aviation black box principle in pediatric cardiac surgery: tracking all failures in the pediatric cardiac operating room.	2015	Bowermaster R, et.al.	J Am Coll Surg.	Pediatric Cardiac Surgery
4	NR	Level VI	A = High	CT hospital slashes door-to-balloon times to reduce patient harm.	2014	Allen S, et.al.	ED Manag.	1 hospital
5	NR	Level VII	B = Good	Culture of safety.	2015	Hershey K.	Nurs Clin North Am.	0
6	R	Level VI	A = High	Development and applicability of Hospital Survey on Patient Safety Culture (HSOPS) in Japan.	2011	Ito S, et.al.	BMC Health Serv Res.	13 acute general hospitals (6,395 HCW)
7	NR	Level VI	B = Good	Do we need a national incident reporting system for medical imaging?	2012	Itri JN, et.al.	J Am Coll Radiol.	0
8	NR	Level VI	B = Good	Establishing a culture of perinatal safety in a community hospital.	2011	Phelan JP, et.al.	J Healthc Risk Manag.	0
9	R	Level VI	A = High	Evaluating ambulatory practice safety: the PROMISES project administrators and practice staff surveys.	2015	Singer SJ, et.al.	Med Care.	25 Adult Primary Care facilities, 482 staff MD, PA, NP, Nurses, administrators
10	NR	Level VI	A = High	Failure mode and effects analysis: too little for too much?	2012	Dean Franklin B, et.al.	BMJ Qual Saf.	0
11	NR	Level VII	A = High	Good people who try their best can have problems: recognition of human factors and how to minimise error.	2015	Brennan PA, et.al.	Br J Oral Maxillofac Surg.	0
12	NR	Level VII	A = High	High reliability organizations and surgical microsystems: re-engineering surgical care.	2012	Sanchez JA, et.al.	Surg Clin North Am.	0
13	NR	Level VII	A = High	Highly reliable health care in the context of oncology nursing: Part II.	2014	Sheridan-Leos N.	Clin J Oncol Nurs.	0
14	R	Level VII	A = High	High-reliability emergency response teams in the hospital: improving quality and safety using in situ simulation training.	2013	Wheeler DS, et.al.	BMJ Qual Saf.	596 multi-d staff (MD, RN, RT, CRNA, Surg Tech, Chaplain, Med Student, Pharm)

#	Method	Results	Similarities / differences	Unknown Factors, Risk Issues, and Resource Issues	parts of issue this article pertains to	Recommendations we should consider implementing
1	QI methodology, IHI Healthcare Improvement Model	Decrease in SSE, PHI, PU, ADE, HAI	Hospital focus	Increased QI Dept personnel from 8 to 33 from 2007-2012 and budget 690k to 3.3mil	Multifaceted approach	"Zero Hero" patient safety program/multidisciplinary micro-system based teams
2	QI methodology, PDSA/Quality Collaborative Model	76.5% reduction in the rate of harmful ADE	ICU and pediatric focus	QI huddle program produced 300 huddle recommendations- 92% of them implemented	Huddle-Bundle	ADE prevention bundle/Post-medication error apparent cause "huddle process"
3	QI methodology, Recording surgeries	With systematic capture, event rates increased from 20% to 50%, communication contributed to adverse events	Pediatric Cardiac Surgery	applicability to other specialties	Preoccupation with failure/Communication issues	Aviation black Box Principle/tracking equipment failure
4	QI methodology	Decrease from 90min to 46.5min	Cardiac Cath	applicability to other specialties	High reliability techiques	Training all staff on high reliability techniques
5	Review	0	Hospitals/Nursing	0	Trust/Report/Improve/Second Victim (Resilience)	Nonpunitive response to error/handoffs and transitions/ safe staffing
6	Compared American HSOPS to Japan HSOPS	AHRQ HSOPS provides the best fit for Japan	Healthcare delivery system	Done in Japan	Survey	Dev HSOPS for MHS
7	Review, General Radiology Improvement Database (GRID)	0	Radiology	0	reporting system	GRID
8	Review	0	Community Hospital	0	culture of safety	tracking-evaluation of care, critical events drill
9	Randomized Control Trial involving 25 adult primary care practices	staff perception of suboptimal processes correlated with concerns about vulnerability to malpractice suits	Ambulatory Care	PROMISES not validated but based on 2 previously validated survey	survey, culture of safety	PROMISES Survey
10	Review, Failure Mode and Effect Analysis	FMEA should be used for qualitative instead of quantitative	FMEA is a requirement for Joint Commission	FMEA has questionable quantitative metrics, not used the same across teams	prospective risk assessment	FMEA to bring multi-d team to look at processes qualitative
11	Review, Reason Swiss Cheese, Human Factors Analysis Classification System (HFACS)	0	Hospital and surgery focus	0	human factors that can lead to error	Reason's, swiss cheese model, Human Factors Analysis Classification system (HFACS)
12	Review, Reason Swiss Cheese, Microsystems	0	Hospital and surgery focus	0	microsystem approach to high reliability	microsystem, 6 priniciples for safe surgical microsystems
13	Review, High Reliability Organizing	0	Oncology	0	High reliability techiques, Collective Mindfulness	High reliability science
14	Crew resource management, In situ simulations	64/112 in situ simulations (57%) identified 134 latent safety threats	Done in PICU, CICU, OR, Inpt units	0	in situ simulation to identify latent error	Utilize in situ simulation to identify latent errors

#	Type of Evidence/ Study	Strength of Evidence	Quality of Evidence	Title	Year	Author	Journal	Sample Size / Adequate?
15	NR	Level VI	A = High	Impact of multidisciplinary simulation-based training on patient safety in a paediatric emergency department.	2013	Patterson MD, et.al.	BMJ Qual Saf.	289 participants
16	NR	Level VII	A = High	Improving the quality of health care: what's taking so long?	2013	Chassin MR.	Health Aff (Millwood).	0
17	R	Level VI	A = High	Interventions employed to improve intrahospital handover: a systematic review.	2014	Robertson ER, et.al.	BMJ Qual Saf.	29 paper
18	R	Level VI	A = High	Junior doctors and patient safety: evaluating knowledge, attitudes and perception of safety climate.	2013	Durani P, et.al.	BMJ Qual Saf.	527 junior doctors
19	NR	Level VII	A = High	Key Concepts of Patient Safety in Radiology.	2015	Larson DB, et.al.	Radiographics	0
20	R	Level IV	A = High	Large scale organisational intervention to improve patient safety in four UK hospitals: mixed method evaluation.	2011	Benning A, et.al.	BMJ	
21	NR	Level VII	B = Good	Learning from accident and error: avoiding the hazards of workload, stress, and routine interruptions in the emergency department.	2011	Morrison JB, et.al.	Acad Emerg Med.	0
22	R	Level VI	B = Good	Measuring ward-based multidisciplinary healthcare team functioning: a validation study of the Team Functioning Assessment Tool (TFAT).	2013	Sutton G, et.al.	J Healthc Qual.	110 multi-d team (12/team avg)
23	R	Level VI	A = High	National pediatric anesthesia safety quality improvement program in the United States.	2014	Kurth CD, et.al.	Anesth Analg.	19 institutions, 39 anesthesiologist
24	NR	Level VII	A = High	Ohio Children's Hospitals' Solutions for Patient Safety: A Framework for Pediatric Patient Safety Improvement.	2015	Lyren A, et.al.	J Healthc Qual.	6 Ohio hospitals
25	NR	Level VI	A = High	Our journey to zero: reducing serious safety events by over 70% through high-reliability techniques and workforce engagement.	2012	Hilliard MA, et.al.	J Healthc Risk Manag.	Children's hospital system
26	R	Level VI	A = High	Patient safety climate (PSC) perceptions of frontline staff in acute care hospitals: examining the role of ease of reporting, unit norms of openness, and participative leadership.	2015	Zaheer S, et.al.	Health Care Manage Rev.	118 general acute care hospitals
27	NR	Level VII	B = Good	Patient safety in anesthesia: learning from the culture of high-reliability organizations.	2015	Wright SM.	Crit Care Nurs Clin North Am.	0
28	R	Level VI	A = High	Performance characteristics of a methodology to quantify adverse events over time in hospitalized patients.	2011	Sharek PJ, et.al.	Health Serv Res.	10 North CarolinaHospitals (2400 medical records)
29	NR	Level VII	B = Good	Quality and safety in pediatric hematology/oncology.	2014	Mueller BU.	Pediatr Blood Cancer.	0
30	R	Level VI	A = High	Reflections on the Canadian MORE(OB) obstetrical risk management programme.	2013	Milne JK, et.al.	Best Pract Res Clin Obstet Gynaecol.	Canada OB health system

#	Method	Results	Similarities / differences	Unknown Factors, Risk Issues, and Resource Issues	parts of issue this article pertains to	Recommendations we should consider implementing
15	Safety Attitudes Questionairre pre and post simulation drills	Preintervention baseling of 2-3 safety events/year, has sustained more than 1000 days without a pt safety event	Emergency department	0	Multi-d simulation based training to decrease error	simulation based training for multi-d team
16	Review	0	Healthcare delivery system	0	High reliability organizing to decrease preventable error	High reliability science, robust process improvement
17	Systematic Review	29 studies out of 631 citations used. Current lit does not confirm any method improves outcome, however info transfer shows change	0	0	pt handover, pt transfer	intrahospital handover
18	Junior Doctor-Patient Safety Attitudes and Climate Questionnaire	Study demonstrates subtle differences in attitudes in pt safety among junior doc in diff grades/spec	Junior doctors	0	safety attitudes questions	Junior Doctor-Patient Safety Attitudes and Climate Questionnaire
19	High Reliability Organizing	0	Radiology	0	culture of safety	Human error education, just culture, high reliability performance,
20	Mixed method evalution involving 5 substudies before and after design, interviews, surveys, quality of care, outcomes	improvement in vital sign monitoring, one measure of staff perception, no additional change in other targeted areas	Healthcare delivery system	gaps between strategic level and tactical level	Patient safety initiatives	Independent evaluations of our patient safety initiatives
21	Review	0	Emergency department	0	learning from normal accident error, managing interruptions	Assess amount of interruptions within workplace
22	Observational ratings of team functioning, psychometric testing	TFAT reliable/valid tool measuring team member non-technical skills (clinical planning, executive tasks, team functioning	10 hospital sites in Australia	similarities and differences in healthcare delivery	Assess non-technical skills of multi-d teams	Utiltize the Team Functioning Assessment Tool to assess non-technical skills of multi-d teams
23	QI methodology, Safety analytics	1.4 SAE per 1000 anesthestics, 734 SAE out of 736,365 anesthetics	Anesthesiology	0	utilizing safety analytics and QI methodology	utilizing safety analytics and QI methodology to decrease Serious adverse events
24	QI methodology, PDSA, Task forces	SSE decreased by 55%, equating to 70 children per year who experienced SSE	Pediatric	0	collaborative organizatioal frameworks to decrease error	Align task forces by: Error Prevention, Leadership Methods, Cause analysis, lessons learned
25	QI methodology, Customized error prevention strategy	Reduced SSE by 70%, financial savings of $35mil over a 3 year period	Pediatric, multiple hospitals	0	high reliability techniques and workforce engagement to reduce SSE	Safety governance, employee accountability, error prevention strategies, reporting and cause analysis, SA and engagement
26	Cross sectional study design, Questionairre	ease of reporting, unit norms of openness, and participative leadership are positively r/t perceptions of pt safety climate	hospital systems	Canadian delivery of healthcare	Perception of front line staff of patient safety climate (PSC)	Modified Standford Instrument (MSI)-2006 survey
27	Review	0	0	0	HRO culture	Reason swiss cheese theory, human factors, levels of situation awareness
28	Retrospective Study in a stratified random sample of 10 North Carolina hospitals	High specificity, moderate sensitivity, and favorable interrater/intrarater reliability of GTT make it appropriate for tracking local/national AER	Multi-hospital system	0	Utilizing the Institute for Healthcare Improvement Global Trigger Tool (GTT)	Utilizing GTT to track local and national AER
29	Review	0	pediatric specialty	0	high reliability techniques, quality, safety	Sustain TeamSTEPPS, IHI triple aim of experiencing care
30	Culture Assessment Survey CAS) tool	5-20% increase to CAS over a 3 year period	Multi-hospital system	Canadian delivery of healthcare	OB specialty approach to promote pt safety	Manage Obstetrical Risk Efficiently (MORE) OB platform, CAS tool

#	Type of Evidence/ Study	Strength of Evidence	Quality of Evidence	Title	Year	Author	Journal	Sample Size / Adequate?
31	R	Level VI	A = High	Retrospective medical record evaluation: reliability in assessing causation, preventability, and disability of adverse events.	2012	Verelst S, et.al.	Int J Health Care Qual Assur.	Belgium health system
32	NR	Level VII	B = Good	Team training: a safer future for neurointerventional practice.	2011	Miguel K, et.al.	J Neurointerv Surg.	0
33	R	Level VI	A = High	The Global Trigger Tool shows that one out of seven patients suffers harm in Palestinian hospitals: challenges for launching a strategic safety plan.	2013	Najjar S, et.al.	Int J Qual Health Care.	Palestinian health system
34	NR	Level VII	A = High	The Journey to High Reliability in the NICU.	2015	Bondurant PG, et.al.	J Perinat Neonatal Nurs.	0

#	Method	Results	Similarities / differences	Unknown Factors, Risk Issues, and Resource Issues	parts of issue this article pertains to	Recommendations we should consider implementing
31	Retrospective medical record review with 2 review teams	New insight on the degree of and reasons for huge differences in adverse event evaluation	Multi-hospital system	Belgium delivery of healthcare	Medical record evaluation	Assess reliability in assessing causation, preventability, and disability of AE
32	Review	0	specialty care		0 team training	crew resource management
33	Retrospective review using medical records using the GTT	1 out 7 patients (14.2%) suffered harm, 54 (59.3%) were preventable, 64 (70.4%) resulted in temporary harm and prolonged hospitalization	Multi-hospital system	Palestinian delivery of healthcare	Global trigger tool	Global trigger tool to assess medical records
34	Review	0	NICU		0 journey to achieve high reliability	HRO principles at tactical level

Source: Created by author.

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